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GROWTH AND FLOWERING OF CLONES OF SLASH PINE UNDER INTENSIVE CULTURE: EARLY RESULTS

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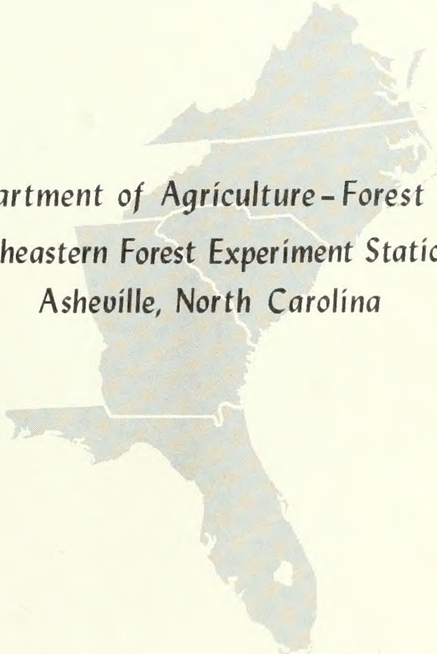

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Asheville, North Carolina

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GROWTH AND FLOWERING OF CLONES OF SLASH PINE UNDER INTENSIVE CULTURE: EARLY RESULTS

By

George W. Bengtson

SUMMARY

In 1959, a slash pine (*Pinus elliottii* Engelm. var. *elliottii*) plantation was established in Baker County, Florida to permit long term investigations of the effects of inherent and environmental factors on the performance of this species. This is the first of a series of publications expected to originate from this unique plantation.

Some 24 clones were created through vegetative propagation of ortets of known parentage, growth characteristics, flowering habit, and gum-yielding potential. One ramet of each clone was established in each of the 24 treatment cells, comprising a 2x2x2 factorial experiment in three replications. The cultural treatments consisted of irrigation vs. no irrigation, fertilization vs. no fertilization, and disking vs. ground cover (a summer legume). Trees were planted at orchard spacing (20x20 feet) on an intensively prepared old-field site.

Through the first 4 years of study, overall effects of irrigation, fertilization, and ground cover on growth of the trees were not significant. However, legume cover significantly reduced both height and diameter growth in nonirrigated plots while increasing height growth slightly on irrigated plots.

On all plots, nitrogen (N) and phosphorus (P) content of foliage was generally above levels associated with deficiency and reduced growth rate of slash pine. Applications of N and P fertilizers soon after the trees were established did not increase N and P content of tree foliage. The lack of increase in N content is believed a consequence of slow and incomplete release of N by its source (Uramite),[1] and by leaching of mineralized N through the sandy soil. Relatively high soil P probably accounts for the lack of increase of foliar P following fertilization with superphosphate.

The cultural treatments affected flowering rather strongly. Over a 3-year observation period, as the trees bore their first flowers, the most female strobili were produced on disked, nonirrigated plots. Male strobili were also more abundant on disked plots, but were increased by irrigation.

The observed effects of ground cover and irrigation on female flowering appear to result mainly from their influence on availability of N to the trees, although disking may have exerted an additional "root pruning" effect. Foliage analysis and flowering correlations indicate the legumes competed with the trees for N during the critical summer months when female strobili were initiated, thus reducing female flower production. Irrigation also reduced foliar N content and production of female flowers, presumably through rapid leaching of N from the soil. Male flowering behavior was not closely related to foliar N levels nor to foliar content of other nutrients.

The magnitude of difference in flowering between cultivated and legume-planted treatments is decreasing with time, and may be related to accumulative changes in the soil N pool. Soil analyses of samples collected during the dormant season showed significant increases in total N on legume-planted plots and significant decreases on disked plots at the close of the 4-year observation period. Available P and exchangeable potassium (K) were not affected by treatment. Great increases in exchangeable calcium (Ca) and magnesium (Mg) and soil pH resulted from high Ca and Mg content of the irrigation water.

Highly significant clonal differences were observed in growth rate, nutrient content of foliage, and flowering characteristics, including precociousness, fecundity, and sexuality. Clonal variation in nutrient accumulation in the foliage showed no clear relation to growth rate, flowering, or gum yield potential. Significant correlations in growth rate and cone and conelet production were observed between ortets and ramets.

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[1] Commercial products are mentioned solely for purposes of information. Endorsement of products is neither intended nor implied by the Southeastern Forest Experiment Station.

INTRODUCTION

Wide differences in growth rate and other characteristics are common among individual southern pine trees and stands. In seeking causes of this variability, it is often difficult to distinguish between inherent and environmental influences. This is partly because the southern pine species, unlike horticultural varieties, are of considerable genetic diversity (Squillace 1966). Consequently, two neighboring trees of the same species probably do not have the same genetic potential and thus may not respond in the same way to a particular set of environmental conditions (Pritchett and Goddard 1967). Similarly, groups of trees of different geographic origin may show significant variation in performance when planted over a series of different habitats.

Adding to the problem, forested areas are often (and not always obviously) heterogeneous in soil properties and micro-relief. Consequently, wide variations in tree-growth rate over relatively short distances are often largely the result of unsuspected environmental factors.

Until recent years, debate over the heredity-environment dichotomy was futile to foresters because economic factors largely precluded their doing anything to improve either the genetic constitution of their tree stock or its environment. This is no longer the case. Tree breeding, site preparation, and fertilization now claim major roles in forest research, and will no doubt occupy increasingly important roles in the silviculture of tomorrow.

To provide better understanding of and appreciation for the influence of inheritance and environment, and their interactions, on various performance characteristics of the important slash pine (*Pinus elliottii* Engelm. var. *elliottii*) species, workers at the Southeastern Forest Experiment Station began a unique experiment in 1957.

This experiment, which involved the creation of 24 slash pine clones[2] by vegetative propagation and the establishment of three ramets of each clone in eight environmental treatments, is beginning to yield useful results. This progress report presents these early results along with some tentative conclusions concerning them. Its main function, however, is to sketch briefly the advantages and problems incident to the experimental design and treatments employed, and to set the stage for reports of comprehensive investigations underway in and planned for this unusual research installation.

OBJECTIVES OF THE EXPERIMENT

The study was originally conceived to evaluate the effects of irrigation, fertilization, and ground cover on the growth and oleoresin yields of 24 *individual* slash pine trees (genotypes) growing on a typical pine orchard site. The study has also provided, or will provide, the opportunity for evaluating genetic and environmental influences upon production of male and female strobili and seed, and susceptibility of the trees to diseases and insects. It is also expected to permit assessing effects of these factors on the physical and chemical properties of the wood and oleoresin produced.

The experiment was also intended, and has served well, to point up some practical problems of intensive culture in pine orchards (Bengtson and Goddard 1967).

PROCEDURE

Planting Site

Most of the better sites for slash pine orchards in the Southeast are found on abandoned farms. The land is usually well-drained, free of pine heartwood stumps, easily accessible by vehicle, and sometimes relatively fertile. Since it was desirable to use a site similar to those being planted to pine orchards in the Southeast, we selected an abandoned pecan orchard on the Olustee Experimental Forest.

The area was mapped by Soil Conservation Service specialists and found to consist mainly of soil of the Blanton series. This deep and excessively drained, naturally infertile sand commonly occurs on low ridges between ground-water podzols of the flatwoods. The soil properties[3] (see tabulation below) showed similarity to most virgin Blanton profiles. Exceptions were high P content, probably a fixed residue from past fertilization, and high Ca content, mainly a function of residual lime and of localized patches of mortar fragments from old building pillars and stock tanks.

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[2] A *clone* is a "family" of plants produced by vegetative propagation of a single plant, the *ortet*. The individual members of the clone are called *ramets*. All ramets of a given clone have identical genetic constitutions. Variation in performance among ramets of a single clone can thus be ascribed mostly, if not wholly, to environmental influences.

[3] Nitrogen was determined by macro-Kjeldahl analysis procedure; organic matter by Walkley-Black procedure; available P by Bray #2; and exchangeable K, Ca, and Mg extracted with ammonium acetate at pH 7.0 and analyzed by flame spectrophotometry.

In early 1957, remnants of the pecan orchard plus a few scattered pine saplings were bulldozed from the selected area. The site was rootraked, disked to a depth of 6 to 8 inches and fenced, and the plantation laid out essentially within the boundaries of the Blanton soil.

Chemical Properties		Physical Properties	
Total nitrogen	328 ppm	Sand	92 percent
Organic matter	1.09 percent	Silt	5 percent
Available phosphorus	189 ppm	Clay	3 percent
Exchangeable potassium	17 ppm	Pw (15 atmos.)	2.57
Exchangeable calcium	393 ppm	Pw ($\frac{1}{3}$ atmos.)	3.42
Exchangeable magnesium	38 ppm		
Soil pH	5.70 units		

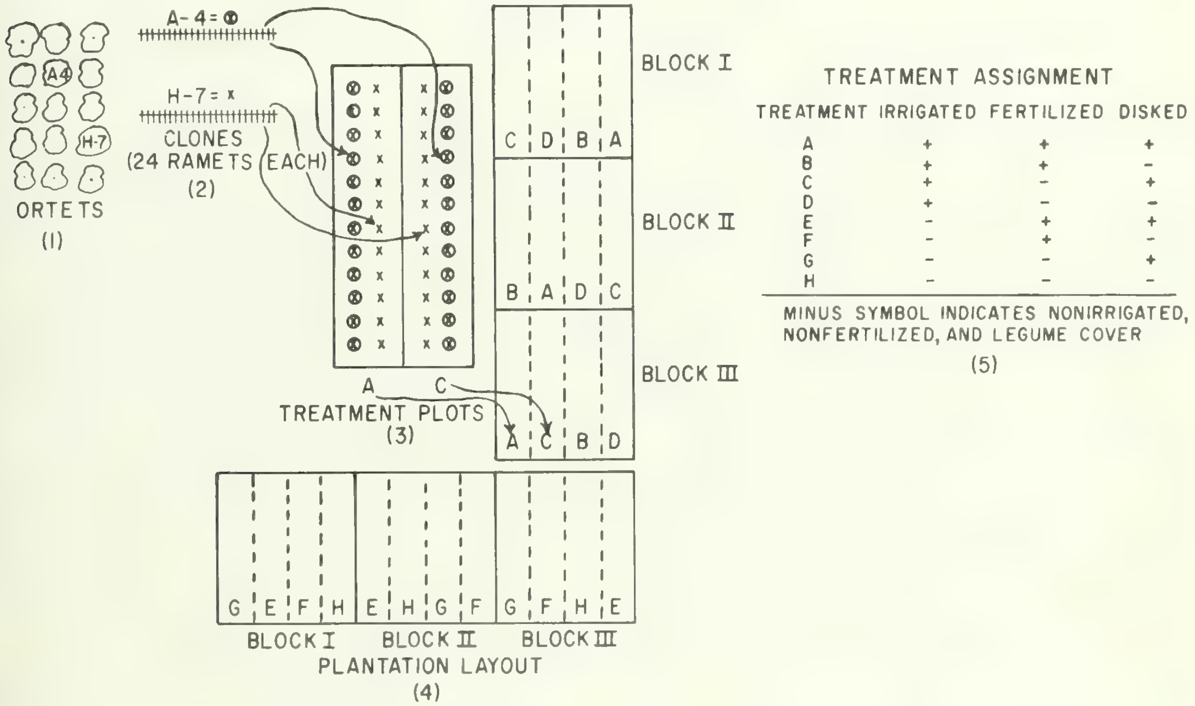
Planting Stock

The 24 ortets used in the experiment were selected from a 15-year-old progeny test plantation. This material was used because parentage of each ortet in the plantation was known, as was its growth performance, wood specific gravity, cone production, and gum yielding ability. Full sibs, half sibs, and completely unrelated individuals were available for comparison.

Twelve of the ortets selected, designated as "high gum yielders," had in two microchipping evaluations produced twice as much gum as the average tree in the plantation, and had at least one parent rated as a high-yielding phenotype. The other 12 ortets were "average yielders."

No consideration was given to stratification of the sample on other characteristics, such as growth rate or cone production, so the sample may be considered random for these traits, except as they may be associated with gum yielding ability.

In the summer of 1957, airlayering was begun to obtain at least 24 vegetative propagules from each ortet. As the branchlets rooted, they were potted and eventually outplanted in their preassigned cells in the plantation (fig. 1).



TREATMENT ASSIGNMENT

TREATMENT	IRRIGATED	FERTILIZED	DISKED
A	+	+	+
B	+	+	-
C	+	-	+
D	+	-	-
E	-	+	+
F	-	+	-
G	-	-	+
H	-	-	-

MINUS SYMBOL INDICATES NONIRRIGATED, NONFERTILIZED, AND LEGUME COVER

(5)

Figure 1. -Diagrammatic representation of stock arrangement (1) (2) (3), plantation layout (4), and treatment assignment (5).

Some ortets rooted well; others not at all. Substitute ortets were selected as required. Outplanting of ramets proceeded by blocks: block 3 and a few cells of blocks 2 and 1 were planted in the winter of 1957; block 2 was essentially completed about a year later. Twenty of the 24 clones were completely represented in all three blocks by the fall of 1959. Vegetative propagation of the four incomplete clones was stopped at this time and the vacant cells—all in block 1—were planted with common seedlings. The isolation rows were planted with 1-0 common seedling stock in the winter of 1958.

The prolonged period of establishment by blocks gives particular significance to block effects appearing in analyses of the data. Because of the general similarity of soil in the 3 blocks, most significant block effects can be ascribed to age of the stock. However, some unavoidable experimental error results from soil heterogeneity within blocks and from variation in time of establishment and initial vigor of ramets.

The outplanting design is a split block with half the plantation irrigated and half not irrigated (fig. 1). The three split blocks each consist of eight plots comprising a 2x2x2 factorial. Each plot is about ½ acre in size and enclosed with an isolation row of seedling stock. The trees are spaced 20 feet apart. The ramets were systematically placed within plots to permit eventual removal of alternate east-west rows—if such becomes necessary—while maintaining 12 complete clones.

Irrigation Treatment

The split block treatment, irrigation vs. no irrigation, involves application of deep-well water to half the area with permanently placed Rainbird sprinklers [1] (fig. 2). The original intention was to control irrigation with tensiometers, but difficulties in calibrating the instruments and the considerable time required to check and service them forced adoption of an empirical system.

For the first 2 years of the study, the small trees were irrigated to assure them at least 1 inch of moisture per week, year round. One inch of irrigation water was applied whenever rainfall for the previous week was less than 1 inch. Since 1962 (the 3rd year) 2 inches of water have been applied per week during the growing season (March-November) and 1 inch per week during winter months, whenever precipitation in the preceding week has been less than 1 inch (table 1). This schedule is based on Zahner's (1955) estimation of 0.24 inch of evapotranspiration per day from forest stands on moist soil.

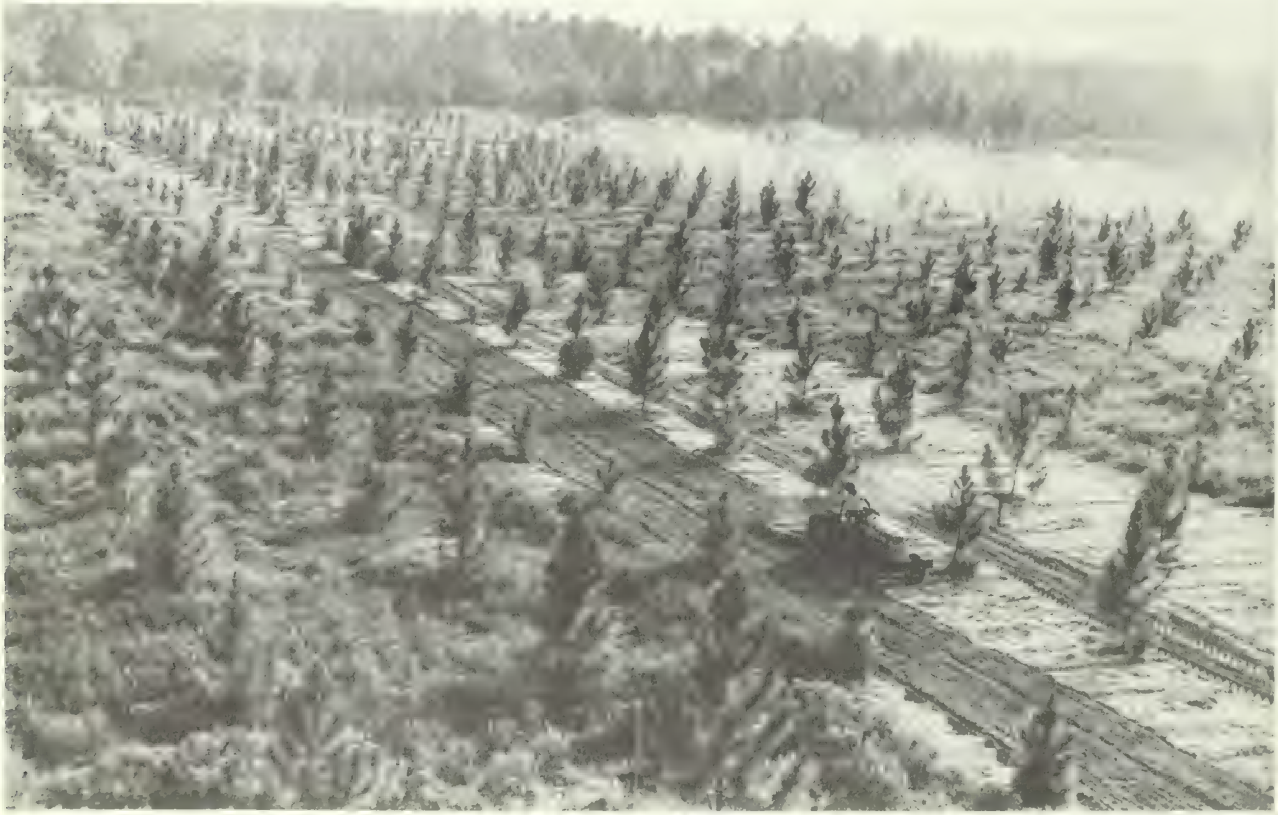


Figure 2.—Aerial view of plantation showing legume cover, disking, and irrigation in August 1961.

Table 1.—Rainfall and irrigation record for 1960 through 1963, Olustee Experimental Forest

	1960		1961		1962		1963		4-year average	
Month	Rain	Irrig.	Rain	Irrig.	Rain	Irrig.	Rain	Irrig.	Rain	Irrig.
					Inches					
Jan.	2.39	2.00	4.75	0	1.68	4.00	0.77	4.00	2.40	2.50
Feb.	5.24	0	2.08	1.00	1.04	4.00	5.26	0	3.41	1.25
Mar.	6.44	0	0.27	4.00	4.34	0	2.08	2.00	3.28	1.50
Apr.	1.99	3.00	5.72	1.00	2.35	8.00	0.80	8.00	2.71	5.00
May	3.25	3.00	1.84	3.00	0.40	8.00	1.65	8.00	1.78	5.50
June	6.74	1.00	6.44	1.00	4.23	2.00	7.25	2.00	6.16	1.50
July	7.45	0	6.33	3.00	6.06	2.00	8.91	0	7.19	1.25
Aug.	4.14	1.00	8.40	0	2.95	4.00	7.51	2.00	5.75	1.75
Sept.	5.51	0	2.13	2.00	6.95	2.00	9.00	4.00	5.90	2.00
Oct.	5.22	1.00	0.39	5.00	1.77	4.00	0	6.00	1.84	4.00
Nov.	0.05	3.00	2.88	2.00	2.75	4.00	2.62	4.00	2.07	3.25
Dec.	2.08	2.00	0.79	3.00	3.02	1.00	3.33	1.00	2.30	1.75
Total	50.50	16.00	42.02	25.00	37.54	43.00	49.18	41.00	44.79	31.25

Note the high summer rainfall and the occasional spring droughts which characterize this area, in which the long-term average rainfall is 50 inches. Thus, 1960 and 1963 were normal in total precipitation, while 1961 and 1962 were below normal.

Fertilization Methods and Materials

The second treatment dichotomy involves the use of fertilizers. Fertilization has been applied stepwise in this study. The nutrients tested to date have been applied individually in the order in which elemental deficiencies have generally occurred on similar sites. This procedure was adopted because the design provides only one fertilized cell and we felt a more penetrating interpretation of fertilizer response, or the lack of it, could be made by proceeding with one element at a time rather than through "shotgun" application.

This approach has involved the following fertilizer applications during the period covered by this report:

Year	Material	Rate	Mode and time of application
1960	Uramite (Kolterman 1956)	0.20 lb. N/tree	Hand broadcast around tree, April
1961	Uramite	0.30 lb. N/tree	Hand broadcast around tree, April
1962	20 percent superphosphate	50 lb. P/acre	Broadcast by spreader, April

Disking vs. Legume Cover

The third cultural treatment compared cultivation (disking) to maintenance of a leguminous ground cover. Disking is done to a depth of 4 to 8 inches, usually 4 times per season. The legume cover (fig. 3) is hairy indigo (*Indigofera hirsuta L.*), a vigorous, reseeding summer legume tolerant of infertile soil (Norris and Lawrence 1962).

Soil and Foliage Analyses

Soil samples were taken from each plot in the winter of 1959 and again in 1963. These consisted of a composite representing the top 6-inch layer. Samples were airdried, sieved through a 2 mm. screen, and analyzed for total N, organic matter content, available P, exchangeable K, Ca, and Mg, and pH using methods described previously.[3]

Foliage samples were collected from all ramets of four clones in August and December of 1961 and from four different clones in 1963. Samples were taken of the oldest needles of the current season on branches in the whorl formed at the base of the overwintering terminal bud. Needle samples were dried at 70° C. and analyzed for content of N (macro-Kjeldahl), P (molybdate-vanadate), and K, Mg, and Ca (flame spectrophotometry). Analyses for Ca and Mg were omitted in 1963.

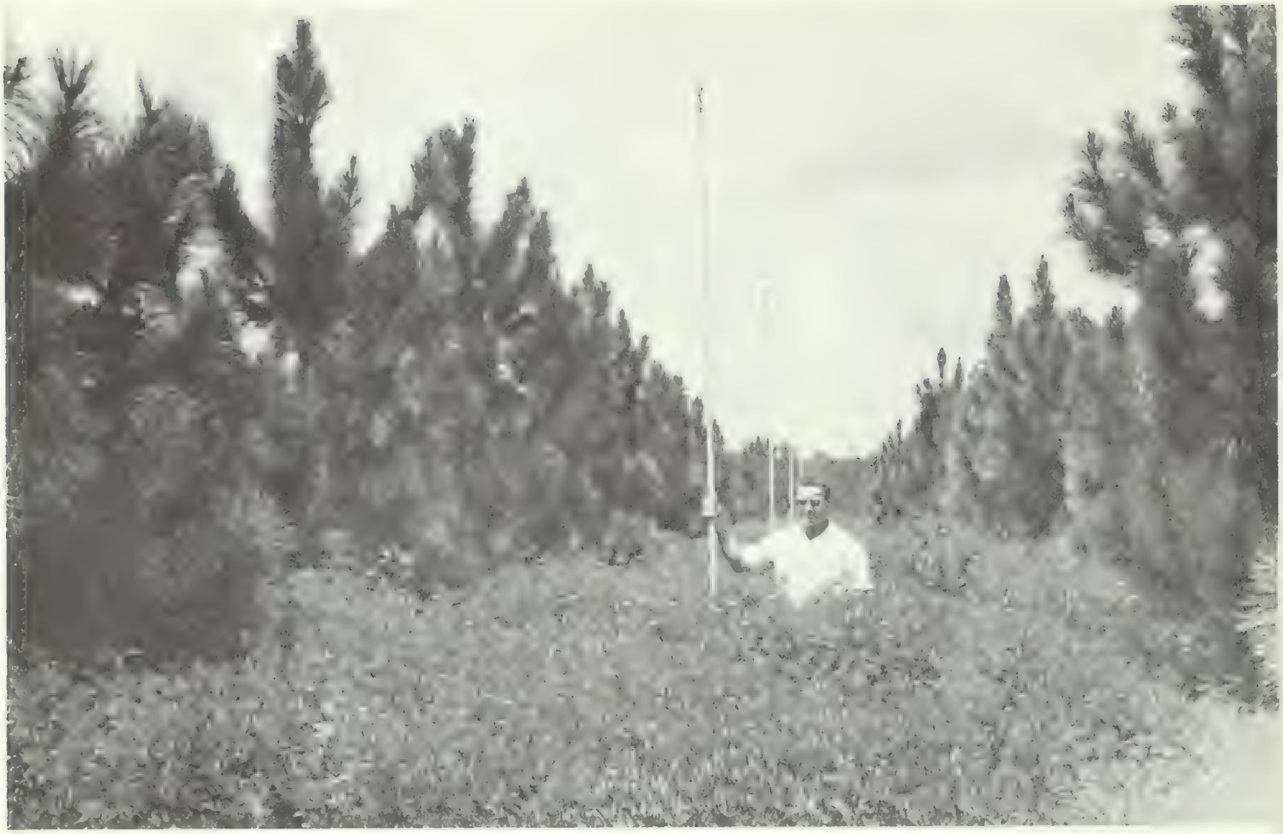


Figure 3.—Hairy indigo stand under young slash pine, photographed in August 1962.

RESULTS AND TENTATIVE CONCLUSIONS

Stem Growth

After 4 years, stem growth of trees in the plantation showed no effect of the fertilizer treatments. Irrigated trees were slightly larger in all treatments, averaging 21.4 feet in height and 5.2 inches d.b.h., compared to 20.5 feet and 4.8 inches for nonirrigated trees. These differences did not attain statistical significance. However, a highly significant interaction of irrigation with ground cover treatment was recorded; the data are tabulated below:

	Height		D.b.h.	
	Disked	Legume Cover	Disked	Legume Cover
	(Feet)		*(Inches)*	
Irrigated	21.1	21.7	5.2	5.2
Not irrigated	20.6	20.3	5.0	4.7

Where irrigation was provided, the legume cover stimulated height growth slightly; without irrigation, legume cover reduced both height and stem diameter growth. On this excessively well-drained site, the legume cover apparently competed significantly with trees for soil moisture during the growing season.

While environmental manipulations had only small effects on tree growth during this establishment phase, rather large and highly significant differences in height and stem growth were observed among clones. The range in average height among clones after 4 years was 16.8 to 23.9 feet. D.b.h. ranged from 3.6 to 6.0 inches. Part of these differences may have resulted from varying times of establishment of clones; however, many of them are undoubtedly genetic differences, as evidenced by significant ortet-ramet growth correlations.

Somewhat surprisingly, no statistically significant interactions of clones with environmental variables were detected. This is probably because, to this stage in development of the stand, little stress has been placed on the growing capacity of the trees by withholding fertilization and irrigation.

Flower Production

Despite the limited data available from these sexually immature trees, some interesting trends were observed in flowering associated with cultural treatments (table 2).

Considering the summed data for all clones, production of female strobili was greater where the trees had *not* been irrigated and where ground cover had been eliminated by disking. Male flowering was also significantly more abundant on disked plots, but was *increased* by irrigation. Thus, while disking increased both male and female flowering, irrigation increased male flowering only, with the overall effect of increasing the proportion of male to female flowers.

A satisfactory explanation for the absence of a fertilizer effect on flowering and for the difference in flower production between disking and legume cover treatments was found in data from foliage and soil analyses.

Pronounced inherent differences were observed among clones in flowering precociousness, fecundity, and sexuality. Ortet-ramet fecundity correlations were significant. In general, flower production by heavy-flowering clones was strongly influenced by environmental manipulations. Near-barren clones were little affected. Clonal tendencies toward a preponderance of male or female flowering showed no effects of environmental variables.

Table 2.—Main effects of cultural treatments on the first three flower crops in the experimental plantation

Date of flower crop	Irrigated	Not irrigated	Fertilized	Not fertilized	Disked	Legume cover
FEMALE STROBILI (Number of conelets)						
1962	189	363*	252	300	364	188**
1963	57	346*	179	224	364	39**
1964	1,241	1,553	1,563	1,231	1,675	1,119*
MALE STROBILI (Number of catkin clusters)						
1964	5,931	3,613	4,901	4,643	5,616	3,928*

*Difference significant at 5-percent level of probability.
**Difference significant at 1-percent level of probability.

Soil and Foliage Analyses

Soil analyses showed that total N in the upper soil horizon was not long affected by the fertilizer treatments, presumably because of leaching of applied N and its incorporation into plant tissue. Legume cover, on the other hand, resulted in a net *gain* of 42 ppm N over the 4-year period (roughly 84 lb. N/acre). Disking produced a net *loss* of 40 ppm N (roughly 80 lb. N/acre) from the top 6-inch soil layer. The N increment in the soil on the legume plots presumably represents atmospheric N fixed by the legumes. The net loss on the disked plots is interpreted as a consequence of increased N mineralization and leaching caused by frequent incorporation of litter into the soil, and the absence of a dense network of roots capable of retaining mineralized N in the soil-plant system.

The only other important change in soil properties was a marked increase in exchangeable Ca and Mg in the soil on irrigated plots, and a corresponding pH increase from 5.7 to 7.0 on these plots. This is a consequence of the high Mg and Ca content of the irrigation water.

Foliage analyses reflect some of these changes in soil properties and help interpret the observed flowering responses.

In 1961, and to a lesser extent in 1963, the N content of foliage from legume-covered plots was *lower* in August and *higher* in December than on disked plots (table 3). This is presumed a consequence of the legumes competing with trees for

Table 3.—Differences in N content of foliage related to treatment and time of foliage collection

Time of sample collection	N content (percent dry weight)			
	Disked	Legume cover	Irrigated	Not irrigated
Aug. 1961	0.92	0.86**	0.87	0.91NS
Dec. 1961	1.14	1.25**	1.15	1.24*
Aug. 1963	0.86	0.84NS	0.81	0.89NS
Dec. 1963	1.01	1.17*	1.01	1.18*

*Difference significant at 5-percent level of probability.
**Difference significant at 1-percent level of probability.

available N during the growing season, and a net increase in available N in winter when the legumes die and are decomposed.

The lower level of female flowering on legume-planted plots may be related to the lower N content in foliage during August. Female flower initiation in southern pines is believed to take place during the summer, and increased N availability in the soil during this period has been found associated with stimulated production of female strobili the following season (Matthews 1963). Conversely, reduced N availability during this period would perhaps reduce female strobili production.

The smaller difference in flower production on disked plots vs. legume-covered plots recorded in 1964 may be interpreted as a consequence of changes in total soil N in these two treatments.

Foliar content of P and K was not greatly affected by any treatment, and in no case was either observed at concentrations normally associated with deficiency. Ca and Mg content of the needles was higher on irrigated plots in the 1961 analysis. However, these data are not reliable indicators of Ca-Mg nutrition of the trees since evaporating irrigation water deposited some Ca and Mg residues on needle surfaces. Surprisingly, the rapid increase in soil pH associated with irrigation has not as yet shown any adverse effects on the trees.

Highly significant differences among clones were observed in foliar content of P, K, Ca, and Mg in 1961, and in N, P, and K in 1963. However, there appeared to be no correlations *within* clones between growth rate or flower production and the foliar content of any of these elements, and no inter-correlations among elements were observed.

GENERAL EVALUATION OF THE RESULTS TO DATE

One of the most vexing problems facing researchers and administrators responsible for an experiment of this kind is the need for communication and interpretation of tentative results. Such results are essential to the catalysis of additional research and improved practice, but shouldn't overstate the case nor prompt unwarranted conclusions.

As conventional agronomic experiments go, 4 years of observation on a single experiment is a long time. But trees are involved here, and at their present stage of development are mere adolescents. Not only are the trees changing in morphological and physiological development, but changing also are the soil properties (under the influence of culture) and the proportion of soil mass in contact with roots. We are also dealing with a specific physical environment and tree species. It is essential, therefore, that all conclusions reached in this report be viewed in this light, and the temptation to make broad extrapolations be avoided.

The results thus far show clearly it was quite worthwhile to obtain control over the genetic variable. In fact, had the design not permitted separation of genetic from environmental factors, i.e., had a random rather than fixed sample of genotype been used, we probably would have been unable to distinguish any environmental effects on tree performance. This feature of the design should prove extremely valuable in subsequent studies in this plantation.

It is unfortunate that the site chosen is a better source of mineral nutrients and soil moisture than we expected. This has precluded early evaluation of variation among genotypes in response to the stresses of mineral nutrient and soil moisture deficiencies. But, we have gained a more detailed appreciation of the nature of influences exerted by genetic factors on slash pine performance. It seems likely that, as the stand closes, environmenta stresses will develop in certain of the treatments and measures of response to culture and of genotype-culture interaction will be obtained.

THE EXPERIMENT'S PROMISE FOR THE FUTURE

The plantation was fertilized with ammonium nitrate prior to the 1965 flower-initiation season. Effects of this treatment, and other cultural factors, on nitrogenous and carbohydrate constituents of flower-producing stems and their subsequent flower crops have been evaluated, and a detailed report has been published (Barnes and Bengtson 1968).

Effects of recent N fertilization and of the high soil pH caused by irrigation on uptake of macro- and micro-nutrients have been investigated by foliar analysis. The results of this study are being prepared for publication.

Influence of cultural treatments on cone and seed production and seed quality are being determined in current evaluations.

The trees were tapped for oleoresin in the 1966 production season. Results are expected to show the relative effects of inheritance and environment on oleoresin flow and qualities.

Observations are being made on genetic and environmental factors related to attack by insects and diseases in the plantation.

As soon as the trees can withstand removal of large wood cores, an evaluation will be made of genetic and environmental effects on wood quality.

The plantation will continue to yield data on the long term effects of irrigation, fertilization, and ground cover on soil properties and slash pine growth.

Eventually the plantation will be worked as a "gum orchard" (Schopmeyer 1956), to measure the productive potential of such a stand. And, perhaps we will test the feasibility of a tapping procedure designed to extend greatly the productive life of high-oleoresin producing trees grown under intensive culture.

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SEEDING HABITS OF SWAMP TUPELO

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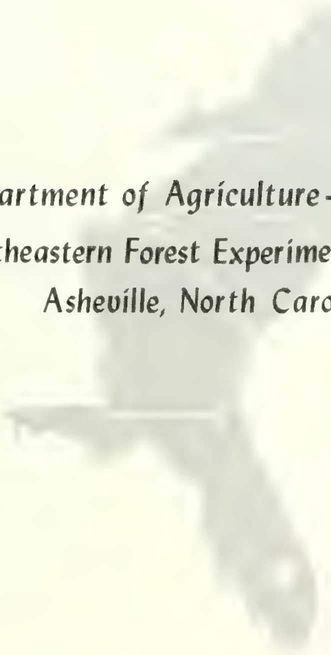

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SEEDING HABITS OF SWAMP TUPELO

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Swamp tupelo (Nyssa sylvatica var. biflora (Walt.) Sarg.) is found primarily in headwater swamps, ponds, and along blackwater and runs in the Southeastern and Gulf coastal plains. Its light-colored wood has good working properties and other characteristics which make it a widely used species in the Southeastern furniture industry. Increasing demands for hardwoods make the wetland sites on which swamp tupelo grows more enticing management propositions than in the past. Unfortunately, present knowledge of swamp tupelo's seeding habits is inadequate for management purposes. There is no information available on seed production and its variation, seasonal seedfall pattern, and time of seed ripening; very little is known about dissemination and germination of the seed. This paper reports on the seeding habits of swamp tupelo in a nonalluvial headwater swamp for a 4-year period, 1963-66.

DESCRIPTION OF STUDY AREA

Bluebird Swamp is about 500 acres in size, located on the Francis Marion National Forest, Berkeley County, South Carolina (fig. 1).[1] Like many other nonalluvial or headwater swamps in the Carolina Coastal Plain, its water level depends upon precipitation and local upland drainage. Although stream channels are not apparent, the swamp drains rapidly during dry periods. The timber is a nearly pure, even-aged (about 90 years) stand of swamp tupelo with only a scattering of baldcypress and red maple. On an average acre there are 245 stems 5 inches d.b.h. and larger, 168 square feet of basal area, and 24 MBF (Scribner Rule) of sawtimber.

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[1] This is a cooperative study with National Forests in South Carolina and Georgia-Pacific Corporation (formerly Williams Furniture Company).

Figure 1.--Bluebird Swamp supports a fine stand of swamp tupelo, a species widely used by the furniture industry in the Southeast.

METHODS

A study area containing fifteen 4.9-acre plots was laid out in Bluebird Swamp during the summer of 1963. Five 1/10-milacre seed traps were randomly located within a 0.9-acre subplot centered in each 4.9-acre plot (fig. 2). Seed trap installation was completed on October 25, 1963; and traps were checked for seed on December 3 and 13 that year. During 1964, 1965, and 1966 seed were collected at 2-week intervals, from early September through January.

Seeds were tallied in three categories: (1) with green exocarp, (2) with dark blue exocarp, or (3) without exocarp. Color was assumed to be indicative of stage of development. Most seed had dark blue exocarps, but some caught early in the fall had green exocarps. In November huge flocks of migrating robins were in the swamp, and many of the trapped seeds had no exocarp--it had been removed by these and other birds. (In this paper, exocarp refers to the fleshy outer covering of fruits and includes both epicarp and mesocarp.)

Standard error of the mean catches in subplots was computed for each year using a standard formula for stratified random sampling.[3] In order to compare subplot variation in different years, the standard error was then expressed as a percentage of the yearly mean.

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[3] Freese, Frank. Elementary forest sampling. U.S.D.A. Forest Serv. Agr. Handbook 232, 91 pp. 1962.

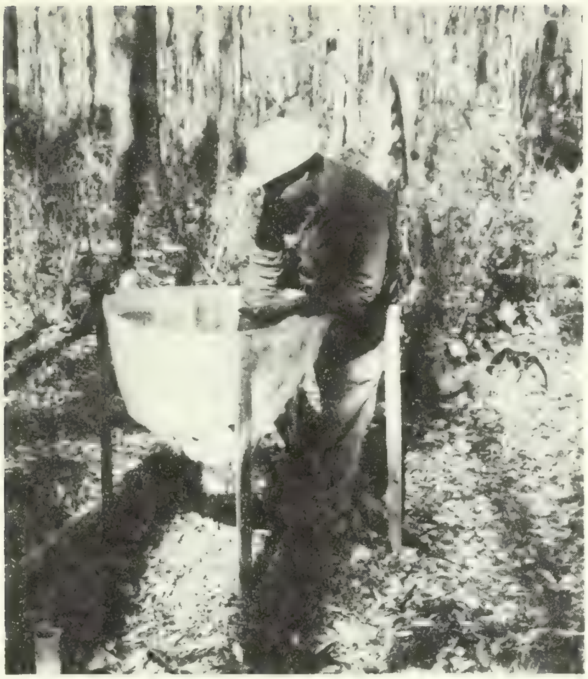

Figure 2.--Seed traps were used in gathering information on production, time of ripening, and pattern of seedfall.

Germination tests were made for the 1965 and 1966 seed crops. Immediately after collection in 1965, seed were separated by collection date, depulped, wetted, placed in polyethylene bags, and refrigerated at 34° to 40° F. In 1966 the seed were treated the same way, except that further separation was made according to exocarp category. After being refrigerated for 3 to 6 months, depending on date of collection, seed of each category were planted in sand flats in early April and thereafter watered daily. Counts were made at 2-day intervals until germination ceased (approximately 60 days).

RESULTS AND DISCUSSION

Variation in Seed Production

Seed production varied widely from year to year, with average catches per trap of 5.5, 0, 68.7, and 83.3 seeds each year (table 1). On a seed-per-acre basis, these figures represent average catches of 55,000 for 1963; 0 for 1964; 687,000 for 1965; and 833,000 for 1966. Because seed collection did not begin until October 25 in 1963, figures for that year probably represent 70 percent of total seedfall (based on fig. 3).

The term $S\bar{y}/\bar{y}$ in table 1 shows that variation in seed production throughout the study area was the same each year, regardless of size of the seed crop. However, relative productivity of individual plots was not the same each year. For instance, the plot which ranked third in 1965 was the least productive in 1966; a plot ranking ninth in 1965 was fourth best in 1966.

Table 1.--Variability in seed production of swamp tupelo, 1963 through 1966

Year	Average number of seed--		Standard error $S_{\bar{y}}$	$S_{\bar{y}}/\bar{y}$
	per trap $(\bar{y})$	per acre		
				Percent
1963	5.5	55,000	0.61	11
1964	0	0	--	--
1965	68.7	687,000	7.65	11
1966	83.3	833,000	9.21	11

The complete seed failure in 1964 may have been caused by late freezes--27° F. March 30 and 24° F. March 31. The long-term weather records of the Charleston airport indicate that average date for the last spring minimum of 28° F. or below is February 28, and for 32° F. or below it is March 17.[3] In addition to the last freeze in 1964 being much later and colder than normal, it was preceded by 2 weeks of warm weather (daily highs in the 60's and 70's and lows in the 40's and 50's). Our observations in Bluebird Swamp, and long-term records of a beekeeping authority,[4] indicate that swamp tupelo usually begins to bloom in late April in the low country of South Carolina. Although flowers were not open when the freezes occurred, the buds were probably susceptible to frost injury.

Seasonal Pattern of Seedfall

Seedfall pattern was similar for the years 1965 and 1966 (fig. 3). Seed began to fall in early September, reached a peak in November, and tapered off during December. By mid-December more than 95 percent of the seedfall was complete, but some seed continued to drop until the end of January. Although the seedfall period exceeded 4 months, more than half the seed was caught in November.

On the earliest collection dates in 1965 and 1966, most seed had green exocarps; by early November (apparent ripening time), 94 percent of the seed had blue exocarps (table 2). The arrival of migratory birds coincided with ripening time--a significant portion of the seed collected then was without exocarps. Percentage of bird-cleaned seed increased shortly thereafter and stayed fairly constant throughout the remainder of the season.

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[3] Personal communication from H. Landers, State Climatologist, Weather Bureau, U. S. Department of Commerce, Clemson, S. C.

[4] Purser, W. H. Personal communication based on written records of W. H. Purser, Apiculturist and Professor of Beekeeping, Clemson Univ., Clemson, S. C. 1966.

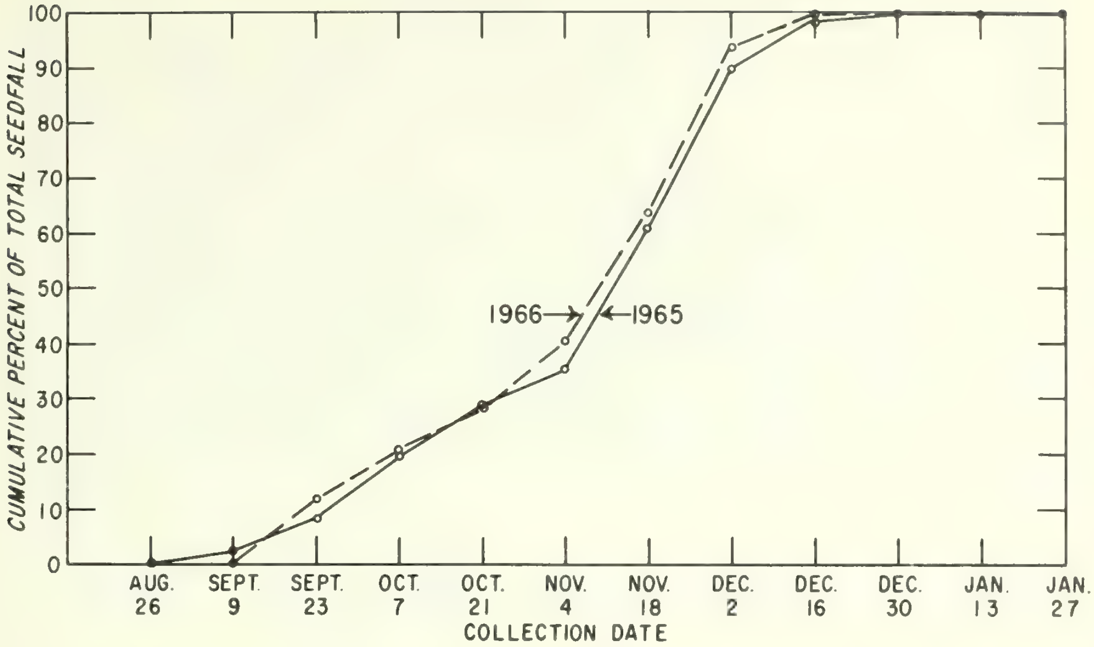

Figure 3.--Pattern of seedfall by date for 1965 and 1966.

Table 2.--Percentage of seed by nature of exocarp and collection date (average for 1965 and 1966)

Nature of exocarp	Collection date									All dates
	September		October		November		December			
	9	23	9	21	4	18	2	16	30	
	Percent[1]									
Green	66	46	21	4	0	0	0	0	0	7
Dark blue	34	54	79	94	74	41	33	38	34	51
Absent (bird-cleaned)	0	0	0	2	26	59	67	62	66	42

[1] All columns total 100 percent.

Dissemination

Seeds are disseminated by two principal agents--gravity and birds. The heavy fruits of the swamp tupelo either ripen and fall or are swallowed by birds and the seed passed through the digestive tract.[5] Of the total seed catch, birds distributed 80 percent in 1963, 38 percent in 1965, and 48 percent in 1966. For periods comparable to that covered by the

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[5] DeBell, D. S., and Auld, I. D. Robins and tupelo in low country swamp. S. C. Wildlife 15(1): 16. 1968.

1963 seed collection (beginning October 25), birds disseminated 45 percent in 1965 and 63 percent in 1966. Dates of arrival and numbers of birds, as well as seed crop size, probably influenced this distribution percentage.

Migrating robins (Planesticus migratorius L.) accounted for most of the bird-distributed seed, mainly because they arrived in huge numbers at the peak of fruit ripeness. Other birds observed feeding on tupelo fruits were bluebirds (Sialia sialis L.), blackbirds (Euphagus spp.), and cedar waxwings (Bombycilla cedrorum Vieillot). The bird-cleaned seed were fairly evenly distributed throughout the stand (fig. 4), and probably this is a major factor contributing to the low and stable variation in yearly seedfall catches ($S\bar{y}/\bar{y}$ in table 1). Most of the seed caught in traps farther than 15 feet from the nearest seed-bearing tree had been dropped by birds.

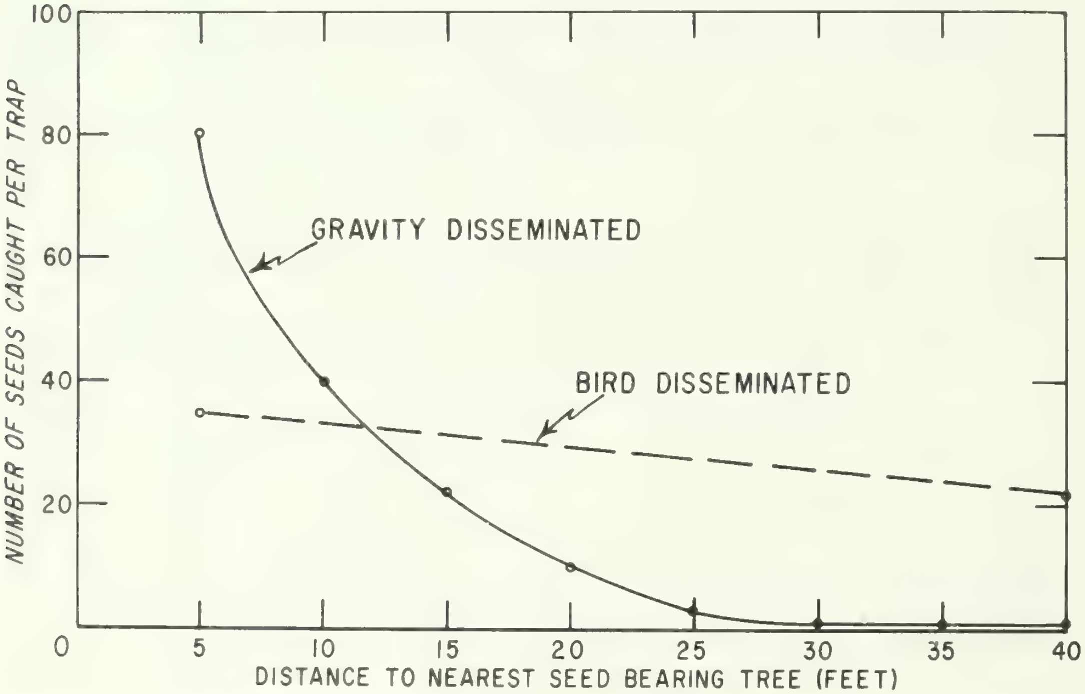

Figure 4.--Relationship of seed trap catch to distance from nearest seed-bearing tree for bird and gravity dissemination (1965 and 1966 averages).

Our observations in Bluebird Swamp and other swamps of the Southeastern Coastal Plain indicate that swamp tupelo fruits sink in water. Researchers[6] working in the Gulf States have reported that drupes and seeds of swamp tupelo float and therefore can be transported for some distance by water. Ecotypic variation could perhaps account for this discrepancy. We have no evidence to justify this assertion other than the fact that swamp tupelo exhibits ecotypic variation in height, weight, and stem form between certain physiographic swamp types within local areas in South Carolina.[7]

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[6] U.S.D.A. Forest Service. Black tupelo (Nyssa sylvatica Marsh.). In Silvics of forest trees of the United States. Agr. Handbook 271, pp. 278-280. 1965.

Germination

The total germination for the 1965 and 1966 seed crops was 57 and 43 percent, respectively. Analysis of variance of germination by collection date showed that significant differences were present, but no pattern was apparent. However, on the average, seed caught during and after peak seedfall seemed to have higher total germination than those caught before. A second analysis of variance revealed the difference in germination between the two periods was significant at the 1-percent level (table 3).

Table 3.--Comparisons of average germination for two seedfall periods in 1965 and 1966

Year	Collection period[1]		Average
	September 10-November 4	November 5-December 16	September 10-December 16
	- - - - - - - - -	Percent germination	- - - - - - - - -
1965	50	65	57
1966	33	53	43

[1] Differences between the collection periods are highly significant.

Germination of 1966 seed also differed according to nature of the exocarp, regardless of time of collection (table 4). Seeds with a green exocarp had the lowest germination. Since these fell mainly in September, they were probably not fully developed. Therefore, seed collections should not be made until the fruit has turned dark blue. Bird-cleaned seed had slightly less (44 percent) germination than those which had dark blue exocarps (51 percent). While the 7-percent difference is statistically significant, it is probably of little importance in the field; the benefit of uniform distribution of seed by birds may far overshadow the loss in viability.

Table 4.--Germination by nature of exocarp

Nature of exocarp	Seeds planted	Germination[1]
	Number	Percent
Green	381	9
Dark blue	1,576	51
Absent (bird-cleaned)	856	44

[1] Differences in percent germination were significant at the 1-percent level.

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[7] Hook, Donal D., and Stubbs, Jack. Physiographic seed source variation in tupelo gums grown in various water regimes. Ninth South. Conf. on Forest Tree Impr. Proc. 1967: 61-64. 1967.

CONCLUSIONS

Our conclusions, based on observations in the Bluebird Swamp, are:

1. Seed crops of swamp tupelo can vary greatly from year to year. Late freezes may be detrimental to seed production.

2. Seedfall occurs during a 4-month period, but more than 50 percent drops during November. By mid-December, 95 percent of the year's seed crop has fallen.

3. Seeds falling during and after the peak seedfall period have higher germination than those falling earlier in the year. For best germination results, seed collections should not be made until exocarps turn dark blue.

4. Birds, primarily robins, play an important and beneficial role in dissemination of swamp tupelo seeds. Although bird-cleaned seeds have slightly lower germination than those with intact dark blue exocarp, the small difference is overshadowed by the benefits of uniform distribution.

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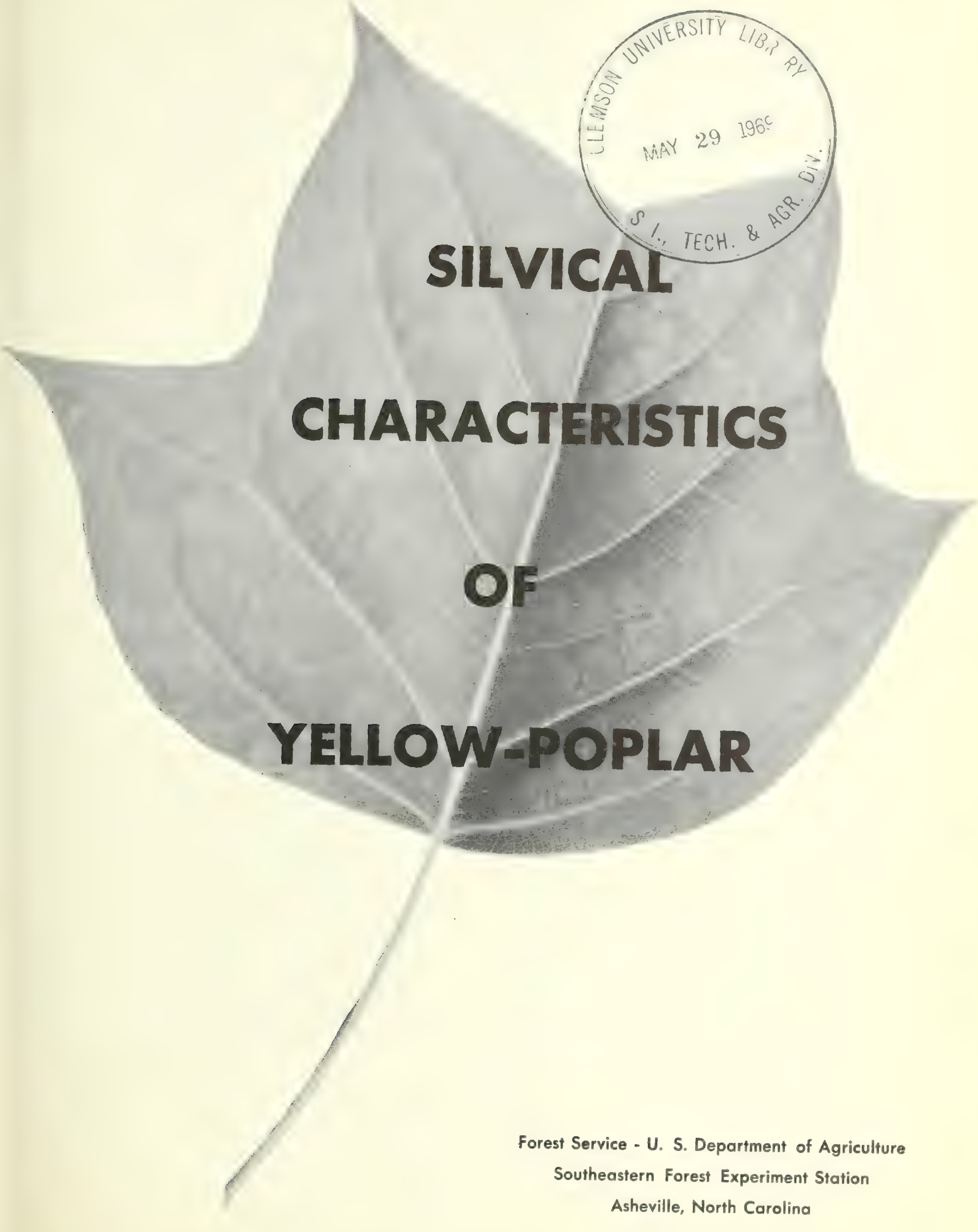

SILVICAL CHARACTERISTICS OF YELLOW-POPLAR

Forest Service - U. S. Department of Agriculture
Southeastern Forest Experiment Station
Asheville, North Carolina

SILVICAL CHARACTERISTICS OF YELLOW-POPLAR[1]

(*Liriodendron tulipifera* L.)

by

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Silviculturist

Yellow-poplar (*Liriodendron tulipifera* L.) is also commonly known as tulip poplar, tulip-tree, white-poplar, whitewood, and "poplar" (*60*). It gets its name from the tulip-like flowers which it bears in the late spring. Because of the excellent form and rapid growth of the tree, plus the fine working qualities of the wood, yellow-poplar is one of the most important hardwood species in the United States.

Yellow-poplar grows throughout the eastern United States from southern New England west to Michigan and south to central Florida and Louisiana. The species is also found in southern Ontario. It is most abundant and reaches its largest size in the valley of the Lower Ohio River Basin and on the mountain slopes of North Carolina, Tennessee, Georgia, Kentucky, Virginia, and West Virginia.

HABITAT CONDITIONS

Climate

Yellow-poplar is widely distributed and grows under a variety of climatic conditions. Temperature extremes vary from severe winters in southern New England to almost frost-free winters in central Florida. Within the range of the species, the average annual maximum and minimum temperatures vary between 100° and —20° F. Rainfall in the territory varies from 30 inches to more than 80 inches in restricted areas of the Southern Appalachians. Yellow-poplar's optimum development occurs where rainfall is well distributed over a long growing season. In a study in West Virginia, adequate rainfall early in the growing season had more effect on diameter growth than did total rainfall during the entire season (*107*). Temperature during the present and past growing season and precipitation during the past growing season showed no relationship to current annual radial growth or height increment (*105*).

Soils and Topography

For good growth and form, yellow-poplar is exacting in soil and moisture requirements. Where it occurs naturally, the sites are usually moderately moist, well-drained, loose-textured soils; it rarely grows well on very dry or very wet sites (*66*). However, in the coastal plain of the Northeast, yellow-poplar also occurs on moderately to very poorly drained soils, where the site index sometimes reaches 110 (*81*).

In the Central States, studies showed that the depth of the A_1 horizon and depth to a tight subsoil are directly correlated with site index; in general, a tight subsoil less than 24 inches below the surface indicates a below-average site (*2, 3*). The studies showed no correlation of site quality with soil nutrient levels or pH.

A soil-site study showed that in the New Jersey coastal plain yellow-poplar grows best in soils with deep, well-drained surface layers overlying loamy or moderately fine-textured subsoils with a good supply of available moisture (*81*). Subsoil mottling had a positive correlation with yellow-poplar site index. Apparently, poor aeration in the subsoil—for some periods of the year at least—is less harmful than is lack of moisture.

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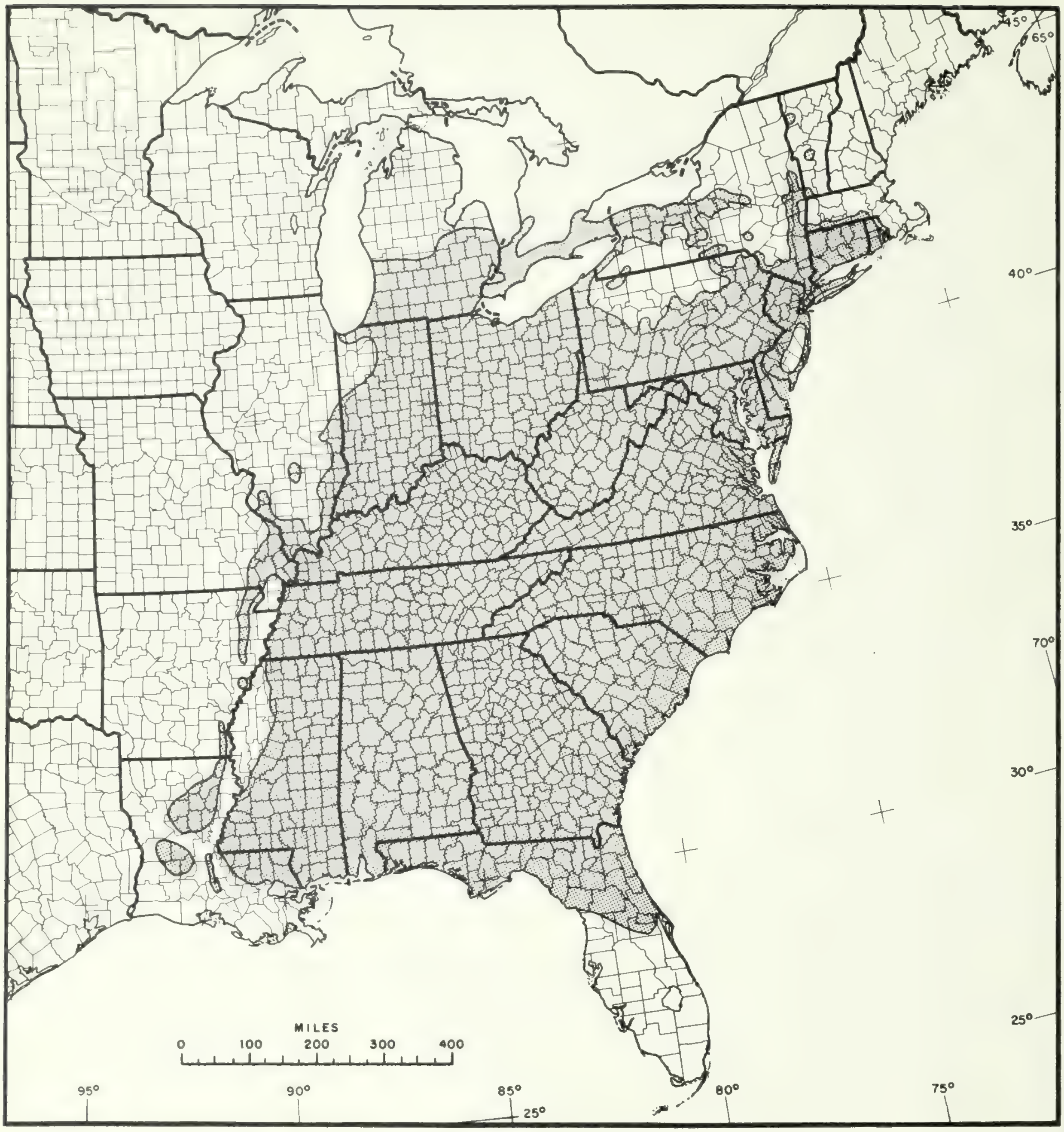
[1] Original authors were James F. Renshaw, deceased, and Warren T. Doolittle, Assistant Director, Watershed, Recreation, Wildlife, and Engineering Research, Northeastern Forest Experiment Station, U.S.D.A. Forest Service, Upper Darby, Pa. At time of authorship, both were employed by the Southeastern Forest Experiment Station.



The range of yellow-poplar.

In another New Jersey study, both physical and chemical soil properties were significantly correlated with yellow-poplar height growth when considered separately; but when the physical and chemical factors were combined in analysis, only the physical soil properties were correlated with tree height growth (*20*).

In one study in the Piedmont of North Carolina, the site indices of yellow-poplar and loblolly pine were found to be similar on good sites. Because of this similarity, the site index of yellow-poplar on lower slopes and alluvial soils can be predicted from an equation for loblolly pine on lower slopes (*18*). Depth of the A horizon and plasticity of the B horizon are the important soil factors in this relationship.[2] Site index increases with increasing depth of the A horizon and greater friability of the B horizon.

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[2] Metz, Louis J. Site indices of yellow-poplar and red gum on alluvial soils in the vicinity of Durham, N. C. 31 pp. 1947. (Unpublished M.F. thesis, School of Forestry, Duke Univ., Durham, N. C.)

Another study of yellow-poplar and loblolly pine in the North Carolina Piedmont showed that there is no difference between the site indices of the two species on good sites.[3] On sites where yellow-poplar is found, depth of the A horizon alone gives an approximate estimate of site quality. In this study, too, site index increased with increasing depth of the A horizon.

In a comprehensive study of the productivity of soils in near-climax Piedmont forests of South Carolina, North Carolina, and southern Virginia, several factors of the soil and topography were found to be correlated with the total height of yellow-poplar (*21*). The factors were topographic position on slope, percentage of organic matter in the A_1 horizon, horizon thickness of the A_1 horizon, thickness of the total A horizon, percent of sand in the A_2 horizon, and geographic latitude. Site index was highest on lower slopes and more northerly latitudes, and was positively correlated with the depth, texture, and organic matter of the soil. While these correlations did not result in strong predicting equations, they do provide important facts about soil and topographic factors that affect the growth of the species.

In a north Georgia study, it was found that site index of yellow-poplar is related primarily to topographic position and to soil series (*43*). Sheltered coves proved to be the best yellow-poplar sites for a given soil series; open coves and the lower portion of sheltered side slopes were next best; ridge sites were poorest. Soils classified as Burton or Tusquitee were unquestionably the best for yellow-poplar.

In a study in Ohio of the effect of nitrogen fertilizer on potted yellow-poplar seedlings, the height growth of the seedlings increased as the amount of nitrogen was increased from 0 up to 100 pounds per acre (*12*). This growth response is in agreement with findings on the Black Rock Forest in New York where yellow-poplar made poor radial growth on nitrogen-deficient soils and approached maximum growth on soils that had a high nitrogen content (*75*).

In central Georgia, yellow-poplar seedlings fertilized with diammonium phosphate had significantly more height growth after 1 year than did unfertilized seedlings (*63*). Three years later the fertilized seedlings were still increasing their height advantage each year over unfertilized seedlings (*42*).

Black locust increased soil nitrogen and improved the growth of yellow-poplar in 24-year-old forest plantations in Ohio and Indiana (*13*). Height and diameter growth of yellow-poplar decreased as distance from the black locust increased. Nitrogen in the soil under the yellow-poplar also decreased with increased distance from the black locust.

Pot-culture studies in Illinois showed that growth of yellow-poplar seedlings was favored by the natural soil structure in forest and plantation soils as compared to old field soil and sieved and packed soil (*15, 16*). The presence of endotrophic mycorrhizae also resulted in increased growth.

Aspect, position on slope (*2, 70*), and elevation are important factors that can influence yellow-poplar site quality because they indirectly influence the moisture and nutrient-supply of the soil as well as the microclimate. At the northern end of its range, where low temperatures are limiting, yellow-poplar is usually found in valleys and streambottoms and at elevations below 1,000 feet. In the Appalachian Mountains, and up to a maximum elevation of 4,500 feet in the Southern Appalachians, it grows on a wide variety of sites including streambottoms, coves, and moist slopes. Toward the southern limit of the range, where high temperatures and soil moisture probably become limiting, the species is usually confined to well-drained streambottoms.

Associated Trees

Yellow-poplar is a component of 16 forest cover types (*92*), being a major species in 4 of these types and a minor species in the other 12:

Major Component

Type No.	Type
57	Yellow-poplar
58	Yellow-poplar—Hemlock
59	Yellow-poplar—White oak—Northern red oak
87	Sweetgum—Yellow-poplar

Minor Component

Type No.	Type
21	White pine
22	White pine—Hemlock
51	White pine—Chestnut oak
52	White oak—Red oak—Hickory
53	White oak
55	Northern red oak
60	Beech—Sugar maple
64	Sassafras—Persimmon
81	Loblolly pine
82	Loblolly pine—Hardwood
90	Beech—Southern magnolia
91	Swamp chestnut oak—Cherrybark oak

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[3] Hocker, Harold W., Jr. Relative growth and development of loblolly pine and yellow-poplar on a series of soil sites in the lower Piedmont of North Carolina. 40 pp. 1953. (Unpublished M.F. thesis, School of Forestry, N. C. State Univ., Raleigh, N. C.)

On bottomlands and the better drained soils of the Coastal Plains, yellow-poplar occurs in mixture with the tupelos, baldcypress, the oaks, red maple, sweetgum, and loblolly pine. In the Piedmont, associated species include the oaks, sweetgum, blackgum, red maple, loblolly pine, shortleaf pine, Virginia pine, the hickories, flowering dogwood, sourwood, and redcedar.

At the lower elevations in the Appalachian Mountains, yellow-poplar is found with black locust, white pine, eastern hemlock, the hickories, white oak, other oaks, black walnut, yellow pines, flowering dogwood, sourwood, sweet birch, blackgum, basswood, and Carolina silverbell. At the higher elevations, associated species include northern red oak, white ash, black cherry, cucumbertree, buckeye, American beech, sugar maple, and yellow birch. Trees associated with yellow-poplar in nonmountainous areas of the North and Midwest include white oak, black oak, northern red oak, ash, beech, sugar maple, blackgum, dogwood, and the hickories.

Pure stands of yellow-poplar occupy only a small percentage of the total land within the range of the species, but pure stands are usually on productive sites which include some of the most valuable timber-producing forests in eastern North America.

LIFE HISTORY

Reproduction and Early Growth

Flowering and fruiting.—Yellow-poplar flowers from April to June, depending on location and weather. The solitary, perfect flower occurs at the tips of slender lateral branches; it is tulip-like in form and size and is one of the favorite sources of nectar for honeybees. In fact, the number of sound seeds produced is apparently related to the number of bees visiting the flowers *(97)*. The fruit is a cone-like aggregate of many winged carpels or samaras borne on a central spike. About 80 samaras are produced in each fruit and each one bears two seeds, one usually aborted. The development of the seed is slow; it reaches morphological maturity between mid-August and mid-September *(34)*.

A study of the embryology of yellow-poplar was made from trees growing in southern Illinois *(48)*. The account presents findings from two successive seasons of normal flower development. The observations indicate that few stigmas receive compatible pollen during their short receptive period; cross-pollination by insects appears inefficient; compatible trees are rarely adjacent; and it is doubtful that wind is effective in transporting the sticky pollen to flowers of other trees.

Seed production and dissemination.—Although yellow-poplar is a prolific seed bearer, few seeds per strobile are fertile—most are empty seedcoats. Whether a samara contains filled seeds or not can be determined by low dosages of soft X-rays *(49, 97)*. Such X-rays have no effect on subsequent seed germination.

Seed of yellow-poplar normally require 2 years or more for complete germination. For germination tests, direct seeding, and nursery seeding, it is desirable to have all viable seed germinate within a few weeks after the samaras are planted. It has been found that storage of seed for 24 weeks at specified alternating temperatures results in germination of all viable seed *(5)*. Temperature cycles of 36° and 54° F. and 36° and 70° F. were both successful.

In an Indiana study, controlled cross-pollination of yellow-poplar resulted in up to 90 percent filled seed per cone, while the highest percentage of filled seed for an open-pollinated tree was 34.8 *(9)*. Four months after germination, seedlings from the cross-pollinated seed parent were taller than seedlings from the open-pollinated parent. It was suggested that, by putting seedlings from widely separated seed parents in the same plantations, seed might be produced that would give both improved germination and more vigorous seedlings. Essentially similar results were obtained in Slovakia in central Europe *(95)*.

In an anatomical and cytological study of seed development, lack of fertilization because of ineffective pollination was found to be the principal cause for nonviable seeds *(6)*. Self- and cross-incompatibilities were judged to be more important factors in the development of poor seed than were tree size or location, position of the cone on the tree, or position of the seed in the cone.

As they dry in the cone, the individual winged samaras are scattered by the wind to distances equal to four or five times the height of the trees *(66)*. In the Piedmont of North Carolina, seedfall begins in early October and reaches a peak in early November *(10)*. Sound seed is disseminated from mid-October to mid-March; and the percentage of soundness is about equal throughout the seedfall period. Dissemination is generally high during warm, dry weather and low during cool, wet weather.

In southern Indiana the seedfall pattern around yellow-poplar seed trees is oval shaped with the center north of the seed tree (*26*). The prevailing south and southwest winds occasionally carry seed over 600 feet.

The minimum seed-bearing age of yellow-poplar trees is about 15 years, and the maximum age is known to be more than 200 years. Bumper seed crops occur at frequent intervals. A study in North Carolina showed that a fall of 300,000 seeds or more per acre is not uncommon (*10*). Cutting tests in this study gave an average of 11.1 percent of sound seeds for a 3-year period; however, cutting tests usually show a much higher seed viability than do germination tests. To cite some examples of production by tree size, a 10-inch tree in the study produced about 750 cones with 7,500 sound seeds, and a 20-inch tree produced 3,250 cones with 29,000 sound seeds. In West Virginia more than 500,000 seeds were produced per acre per year during a 4-year period from 1953 to 1956, and a cutting test on the 1955 crop indicated that 12.4 percent of the seed was sound (*106*). As part of a research program now underway at the Southeastern Forest Experiment Station, measurements of the 1966 seed crop in 16 stands in the Southern Appalachians showed an average fall of 1.5 million seeds per acre.

In a study in Indiana, it was determined that the percentage of filled seed for trees 15 inches or less in diameter was as high as or higher than that for larger trees (*35*). Seed from the upper two-thirds of the crown were better filled than were seed from the lower third. Also, trees in closed stands had about the same percentage of filled seed as did trees in open stands, and seed quality was nearly the same on fertile and poor soil. Another study demonstrated that individual trees in Indiana vary widely in their production of viable seed, and that a given tree consistently produces seed of a given viability (*114*). A low producer will be consistently low, and a high producer will be consistently high over the years. In a study in Ohio, it was found that the percentage survival of year-old yellow-poplar seedlings varied among seed trees within a stand as much as among different stands (*57*).

Seedling development.—The successful establishment of yellow-poplar stands calls for adequate seed, a seedbed of exposed mineral soil (*7*), adequate soil moisture, and direct sunlight (*74*). As a consequence, many of the finest second-growth yellow-poplar stands have become established on old fields in the southern Appalachian Mountains (*19*).

Clearcutting, seed-tree cutting, and group selection have been successfully used to regenerate yellow-poplar. In most cases the extra cost involved in leaving a seed source is unnecessary if seed-producing yellow-poplar were present in the harvested stand.

It is important that the cutover area be large enough for the new crop to grow rapidly. In southeastern Ohio, it was found that yellow-poplar grew faster than oaks after the stand was clearcut (*68*). Combining clearcutting and selection cutting to obtain openings ½- to 1-acre in size also gave good regeneration when a seed source was available. Similar results were obtained in West Virginia where heavier cuttings (including group selection and clearcutting) favored yellow-poplar and other intolerant species on the better sites when a seed source was available (*101*).

While an area is being cut and logged, proper seedbed and light conditions can usually be provided. It is important that the forest floor be scarified (*27*). In the Central States, it was found that yellow-poplar seed in the forest floor retains viability up to 4 years (*17*). When heavy seed crops of viable seed have been frequent for several years, regeneration can usually be obtained with ease following any moderately heavy cut.

Burning following clearcutting has been suggested as a means for preparing a seedbed (*87*). Although this may be a good idea on areas with a heavy accumulation of raw humus, regeneration can usually be obtained without burning.

In a recent study conducted in the coastal plain and Piedmont sections of New Jersey and Maryland, various methods of favoring the establishment and growth of yellow-poplar reproduction were tested (*61*). Most of the regeneration originated from seed stored in the forest floor rather than from current seed crops. Results corroborate the importance of fairly large overstory openings (1 acre or more) and show the need for reduction of understories by burning, disking, or the mistblowing of herbicides. However, such seedbed preparation should be necessary only where deep litter or dense herbaceous growth predominate or where the seed supply is scant.

After germination, several critical years follow. During this period sufficient soil moisture must be available; good drainage and protection against drying and frost heaving are necessary, and there must be no severe competition from nearby sprout growth. In a study in which various mulches were used to induce soil temperature variation, seedlings grew faster in warm soil than in cool soil *(96)*. Soil temperatures up to 97° F. had a beneficial effect on seedling growth. Yellow-poplar seedlings will survive dormant-season flooding, but intensive studies in Georgia showed that 1-year-old seedlings were usually killed by 4 days or more of flooding during the growing season *(64)*. This vulnerability during the growing season explains why yellow-poplar is not found on flood plains of rivers that flood periodically for several days at a time.

On favorable sites the success of regeneration can usually be determined by the size and vigor of the seedlings at the end of the third year. Height growth during the first year ranges from a few inches to more than a foot on the best sites. With full light, rapid height growth begins the second year, and at the end of 5 years heights may be 10 to 18 feet. During its seedling and sapling stages, yellow-poplar is capable of making extremely rapid growth. An 11-year-old natural seedling 50 feet tall has been recorded *(66)*.

Yellow-poplar has a rapidly growing and deeply penetrating juvenile taproot, as well as many strongly developed and wide-spreading lateral roots *(100)*. It is considered to have a "flexible" rooting habit, even in the juvenile stage.

The behavior and duration of height growth of yellow-poplar varies by latitude. In a Pennsylvania study, seedlings had a 95-day height-growth period beginning late in April and ending about August 1 *(44)*. A sharp peak in height growth was reached about June 1. In a northwestern Connecticut study, yellow-poplar had a 110-day height-growth period beginning in late April and ending in mid-August *(52)*. Ninety percent of this growth took place in a 60-day period from May 20 to July 20, and a sharp peak in height growth was noted in the middle of June. In a study conducted in the lower Piedmont of North Carolina, yellow-poplar had a 160-day height-growth period beginning in early April and ending about the middle of September *(56)*. Growth was fairly constant, and there was no peak in growth rate during the growing season.

Winter dormancy in yellow-poplar seedlings can be broken by exposure to low temperatures or by treatment with ethylene chlorohydrin *(55)*. A combination of the two treatments is even more effective in shortening the period before dormancy is broken.

Artificial regeneration.—Experiments in the planting and direct seeding of yellow-poplar have provided important information concerning growth requirements and silvical characteristics of the species.

Artificial regeneration should not be attempted on dry, exposed, old field sites because the few seedlings that survive make poor growth *(66, 71)*.

In the Appalachian Valley of Tennessee, north and east exposures should be favored for planting yellow-poplar and steep south slopes should be avoided *(70, 72, 73)*. The planting site should not be eroded, the soil should be moist but well-drained, preferably with a light-to-moderate cover of vegetation. Other factors affecting plantation success are soil type, first-year precipitation, permeability and porosity of the soil, and rodent activity.

A study of the effect of various preplanting ground treatments on survival and growth of yellow-poplar in the Central States revealed that planting in the lay of double furrows was superior to scalping, single furrow plowing, and no preparation *(69)*. This same study showed that 5-year height growth increased with increases in soil depth and that machine-planted seedlings survived and grew better than bar- or mattock-planted seedlings.

Planting and nursery research on yellow-poplar shows the importance of grading seedlings and improving nursery techniques *(31, 58, 59, 82, 89)*. A study in southeastern Ohio revealed that the heights of 5-year-old seedlings originally graded to a 6/20-inch stem diameter (1 inch above ground line) were 1 foot taller than seedlings of the same age that had been graded to 3/20 inch *(58)*. Seedlings 15 inches high at time of planting were 1 foot taller than seedlings that had been 5 inches high at time of planting. In a North Carolina study, it was found that 3-year survival was significantly greater for seedlings with a root-collar diameter of 0.25 inch or more than for smaller seedlings *(82)*. A combination of root pruning and grading of seedlings can improve survival even more *(59)*. A study of the quality of planting stock revealed that seedbed density exerts some influence on seedling grade, independent of the mother tree *(89)*.

As early as 1931, a study in the Southern Appalachians demonstrated that planting yellow-poplar is more reliable than direct seeding in spots *(54)*. More recently an experiment in direct seeding in the North Carolina Piedmont revealed that yellow-poplar seeds planted in the ground produced more seedlings than did those sown on the surface (*90*). Screen protection of seeded spots increased establishment of the seedlings, and spring seeding gave better results than did fall seeding. In southern Indiana, a direct seeding in forest openings at the rate of 120,000 seeds per acre resulted in 800 seedlings per acre attributable to direct seeding (*14*). An additional 1,000 seedlings per acre were attributable to natural seedfall. Establishment was better on scarified ground than on unscarified ground.

A study in Indiana demonstrated that many soil-site relationships previously established for natural stands also hold true for plantations (*104*). Fifteen-year height growth increased as depth of the A_1 horizon and depth to tight subsoil increased. Survival and growth were satisfactory only where water table depths were greater than 24 inches.

Large differences in height and diameter growth occurred in two portions of a yellow-poplar plantation in southwestern Michigan (*86*). Foliar analysis revealed that the soil-nutrient regimes in the two growth areas were significantly different, especially in nitrogen and phosphorus. Both elements were severely limiting in the poor growth area.

A mixed plantation of 85 percent white pine and 15 percent yellow-poplar was established in 1912 near Baltimore, Maryland (*29*). This is one of the few examples of a successful mixed plantation which includes yellow-poplar as one of the species.

Vegetative reproduction.—A number of investigators have attempted to root yellow-poplar cuttings, but most early attempts were not successful (*4, 41*). In a more recent study, cuttings were rooted successfully after they were dipped in indolebutyric acid and a mist of water was sprayed over the propagation bed (*28*). However, it is not known whether or not these rooted cuttings would have successfully survived outplanting. Yellow-poplar has been successfully

Typical second-growth yellow-poplar stand 45 years of age. This stand occupies a bottom-land site which at one time was a cultivated field.

rooted from stump sprouts of 7-year-old trees (*65, 93, 94*); soft-tissue cuttings placed in a mist bed began rooting in 4 weeks and successfully survived transplanting. Cuttings from a fast-growing clone grew faster, both above and below ground, than did cuttings from a slow-growing clone (*93*). A system of splitting seedlings longitudinally and then propagating the halves was also highly successful (*77*). However, splitting seedlings only provides one additional new plant from the ortet, while the rooting of stump sprouts provides several.

A technique for propagating yellow-poplar by making use of its epicormic branching ability has recently been described (*53*). Partial girdles into the outer one or two annual rings result in a profusion of epicormic sprouts which can then be rooted in the same manner as stump sprouts. This method has the advantage of preserving the selected ortet for repeated use. Experience with this method, however, reveals that not every girdled tree will sprout well. Young trees and trees with low vigor are better sprouters than old trees and rapidly growing trees.

Yellow-poplar sprouts readily and vigorously from stumps and frequently develops satisfactorily in clumps, but sprout stands are not as desirable as stands from seed. Trees of sprout origin are more apt to develop heart and butt rot than are seedlings (*33, 102*). When, as is often done, large, well-formed trees of sprout origin are joined to a suppressed, ancillary stem in a V-type union, several decay fungi usually infect the large tree through the dead stub (*32*). Small stumps provide little support for sprouts against ice and wind damage because the stumps rot quickly, but sprouts from small stumps and seedling sprouts do have high vigor and can usually outgrow the sprouts and seedlings of competing species. It is important to recognize that many existing young stands of sprout origin may need extra cultural attention during the early years.

Sapling Stage to Maturity

Yield and quality.—Mature yellow-poplar trees have reached 190-foot heights and 10-foot diameters, but trees approaching this size are now rare. Good second-growth trees may attain heights of over 120 feet and diameters of 18 to 27 inches in 50 to 60 years (*67*). Probable normal yields for various ages and sites are shown in table 1 (*66*). Table 2 contains selected empirical yields for natural, unthinned yellow-poplar in the Southern Appalachians.[4]

In a study in West Virginia, the average 10-year diameter growth of yellow-poplar by diameter classes was as follows (*38*):

Present d.b.h.	**D.b.h. growth in last 10 years**
Inches	*Inches*
6	3.55
8	3.37
10	3.19
12	3.00
14	2.82
16	2.64
18	2.46
20	2.28
22	2.09
24	1.91

The quality of yellow-poplar trees is also important in determining their value as commercial timber. Quality index is a relative measure of tree value. High quality-index values of yellow-poplar were associated with high site-index values in second-growth Southern Appalachian stands (*8*).

Reaction to competition.—Although it is an intolerant species, yellow-poplar can overcome some competition simply because it grows so fast. In the Piedmont and the mountains of the Southeast, it is extremely sensitive to site change. Several studies in this area have demonstrated

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[4] Unpublished data, Southeastern Forest Exp. Sta., Asheville, N. C.

Table 1.—Normal yield per acre for second-growth yellow-poplar[1]
(Table adapted from McCarthy 1933 (*66*))

Age (years)	Basal area by site indices of—			Volume[2] by site indices of—			Volume[3] by site indices of—		
	70	90	110	70	90	110	70	90	110
	Square feet			*Cubic feet*			*Board feet*		
10	—	8	17	—	50	250	—	—	200
20	39	60	75	600	1,180	1,765	650	2,000	5,180
30	70	97	116	1,305	2,300	3,320	2,650	8,710	15,600
40	97	128	150	2,010	3,390	4,800	6,780	16,300	27,350
50	122	157	183	2,705	4,480	6,220	11,400	24,400	40,200

[1] All trees 5 inches or more d.b.h.

[2] Peeled volume of merchantable stem to a 3-inch top diameter inside bark.

[3] International 1/8-inch rule. Stump height 1 foot; diameter inside bark 6 inches.

Table 2.—Empirical yield per acre for second-growth yellow-poplar in the Southern Appalachians[1]

SITE INDEX 90

Basal area (sq.ft./acre)	Age (years)				Age (years)			
	20	30	40	50	20	30	40	50
	Cubic feet per acre[2]				*Board feet per acre*[3]			
60	1,212	1,668	1,958	2,155	90	972	2,823	4,854
100	2,075	2,857	3,352	3,690	154	1,664	4,834	8,311
140	2,957	4,071	4,777	5,258	220	2,372	6,889	11,845
SITE INDEX 110								
60	1,454	2,002	2,349	2,585	223	2,275	6,257	10,190
100	2,489	3,427	4,022	4,426	382	3,895	10,915	17,449
140	3,548	4,885	5,731	6,308	544	5,551	15,271	24,869

[1] All trees 5 inches or more d.b.h.

[2] Inside bark volume of the entire bole.

[3] International ¼-inch rule. Stump height 1 foot; 11-inch d.b.h. class and larger to top diameter of 8 inches outside bark.

that on the best sites it has the highest site index of all hardwoods and conifers studied, and that on the poorest sites it has the lowest site index (*24, 78, 79*).

Successionally, pure yellow-poplar is temporary. It is often a pioneer on abandoned or clearcut land that has adequate seed and favorable soil-moisture conditions. But it in turn is invaded by more tolerant species, such as oaks, hickories, or northern hardwoods. More often it regenerates as a mixed type with other species, and it commonly persists in climax stands as scattered individuals. In these mixed stands, site quality exerts a strong influence on stand composition. On fertile sites yellow-poplar outstrips most competitors and forms a high percentage of the overstory. On poorer sites other species assume greater importance.

Because this species is intolerant, the cleaning of seedling or sapling stands is an important part of its management (*1, 25, 109, 116*). Dominant and codominant yellow-poplar seedlings or saplings respond little to cleaning, but overtopped or intermediate trees with good vigor respond quite readily in greater height and diameter growth (*25*). A study of yellow-poplar in the Southern Appalachians showed that the greatest benefits of cleaning were more desirable stems and better species composition (*1, 109*). The cleaning also increased yield by 6 cords at 25 years. A New Jersey study showed that competition from understory vegetation under partially cut stands was detrimental to seedling survival (*80*). Shrubs were more detrimental than herbs.

Four years after a clearcut in southeastern Ohio, the best indicators of the growth potential of yellow-poplar seedlings were their immediate past growth and present crown position (*112*). Overtopped trees responded to release, but did not grow as rapidly as did trees that were free to grow from the outset.

In well-stocked stands on good sites, individual tree growth may slow down about the 20th year. Unless the stands are thinned, crowding may continue until growth is seriously retarded. Thinnings made at about 20 years will produce some material large enough for pulpwood, but in most cases stands must be about 30 years old to provide an operable cut. A study in West Virginia showed that moderate thinnings may be desirable at short intervals (*111*). Such thinnings keep a stand sufficiently closed so that epicormic branches do not grow (*110*), nor will the danger from ice or glaze be as great as with heavier thinning (*11*).

Desirable crown length of yellow-poplar can be maintained by repeated thinnings; 60-foot crown lengths are possible when trees reach 100 feet in height (*39*). Moderate to heavy thinnings in which 30 to 40 percent of the volume is removed have been recommended at 8- to 10-year intervals (*40*). Through such intensive management, it may be possible to obtain an annual growth of nearly 1,000 board feet per acre during the last half of the rotation. In the process, basal area growth will be increased, the rotation shortened, and the specific gravity and strength of the wood increased.

Pruning and Epicormic Branching

Yellow-poplar prunes itself well except in very sparsely stocked stands. Consequently, artificial pruning is probably not necessary in natural stands.

Some epicormic branching occurs on yellow-poplar trees, and thinning of young yellow-poplar has often been delayed for fear of causing an increase in sprouting. A recent study in the Southern Appalachians showed that the initiation of epicormic branching on butt logs of second-growth yellow-poplar trees was not related to intensity of thinning.[5] Epicormic branches large enough to cause degrade were concentrated on the upper portion of the butt log. For old-growth yellow-poplar in the Southern Appalachians, epicormic branching increased on residual trees following logging but the increase was concentrated on the upper logs and reduction in value yield was small (*46*). In West Virginia, a comparison of epicormic branching in northern red oak, black cherry, and yellow-poplar border trees showed that yellow-poplar produced the fewest sprouts (*91*).

PRINCIPAL ENEMIES

Yellow-poplar is considered to be unusually free from damage by pests. Though subject to various canker, stain, and decay fungi and to a variety of insect attackers, it is seldom extensively damaged in forest stands. However, with the mounting interest in scenic and recreational areas of high value, damage or loss of even a few individual trees concerns many land managers. With these facts in mind, we have listed and discussed some of the important organisms and agents known to damage the species.

Young yellow-poplar is susceptible to cankers caused by *Nectria magnoliae,* but these cankers soon heal on dominant or codominant trees (*45, 76*).

A canker disease caused by *Fusarium solani* was found on yellow-poplar in Ohio (*22*). The study revealed that the organism is not a virulent pathogen and damages only weakened host trees.

A disease referred to as yellow-poplar dieback was first described in Mississippi in 1954 (*99*). A species of *Myxosporium* was isolated as the probable causal organism. Further work on this disease in the Piedmont of North Carolina cast doubt on this early conclusion and identified an undetermined species of *Xanthomonas* as being consistently associated with the cankered trees (*47*). In North Carolina the disease is more severe in upland sites than in bottomland stands; site, therefore, may be a determining factor in severity of the disease.

Decay often follows top breakage (*83*) or butt wounds from fire (*37*), but these infections may or may not become extensive, depending upon the size of the wound and the specific fungus. Most decay is caused by *Collybia velutipes, Pleurotus ostreatus, Hydnum erinaceus,* and *Polyporus versicolor.* In one study, *Armillaria mellea* was the most common rot affecting fire-damaged trees (*66*). Yellow-poplar is also subject to heart rot in the main stem by way of dead branches. In another study, 20 percent of the dead branches of trees examined were entry points for heart rot into the main stem; the larger the branch, the greater the chances for heart rot (*98*).

The common leaf spots caused by species of *Cercospora, Cylindrosporium, Gloeosporium, Phyllosticta,* and *Mycosphaerella* do not result in excessive damage.

In the Northeast, inoculations showed that infection by *Verticillium albo-atrum* may cause wilting and death of young twigs of yellow-poplar (*113*). Similar wilt symptoms caused by *Verticillium dahliae* were reported in West Virginia (*51*).

Sapstreak, a disease caused by the fungus *Endoconidiophora virescens,* has killed occasional trees. At present, this disease is rare and known to occur only in western North Carolina (*85*).

A nursery root rot disease caused by *Cylindrocladium scoparium* causes root and stem lesions (*50*). It is frequently lethal in nursery beds and causes low survival and poor growth when infected seedlings are outplanted.

Yellow-poplar foliage is occasionally fed upon by larvae of miscellaneous butterflies and moths and by chewing and sucking insects; it is frequently attacked by the tulip gall fly (*Thecodiplosis liriodendri*), which causes purplish blister-galls on the leaves. The branches and twigs may be attacked by several species of scale insects; the most common is the tulip tree scale (*Toumeyella liriodendri*) (*23*). These attacks seldom affect the tree seriously.

Borers occasionally degrade lumber by tunneling in the sapwood or heartwood. Most important is the Columbian timber beetle (*Corthylus columbianus*), a very aggressive ambrosia beetle that enters the sapwood of living trees. The defect, known as "calico poplar," consists of black-stained burrows and discolored wood a foot or more both above and below the point of attack. Dying trees and logs may be injured by the sapwood timberworm (*Hylecoetus lugubris*), and the heartwood beneath the blazes and wounds is often riddled by the flatheaded sycamore borer (*Chalcophora campestris*). Yellow-poplar trees were observed dead or dying along the Cumberland River in Kentucky because of attacks by a root collar borer (*Euzophora ostricolorella*) (*36*). Degrade was not a serious problem in the lumber obtained from a salvage cutting. No new attacks were observed after spraying the basal 6 feet of residual trees with insecticides.

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[5] Della-Bianca, Lino. (Unpublished manuscript, Southeastern Forest Exp. Sta., Asheville, N. C.)

Considerable lumber degrade from "bird peck" is periodically caused by the common sapsucker.

Wood discolorations are common following any type of wounding, but these discolorations, except when associated with decay, do not affect wood strength (*84*). Such nondecay discolorations are attributed to oxidation rather than to infection by organisms.

Yellow-poplar seed form part of the diet of wildlife. Quail, purple finch, cardinal, cottontail rabbit, red squirrel, gray squirrel, and the white-footed mouse are some of the animals that eat yellow-poplar seed.

The twigs and branches of yellow-poplar are tender and tasty to livestock and white-tailed deer, and young trees are often heavily browsed. Seedlings are grazed to the ground, small saplings are trimmed back, and even large saplings may be ridden down and severely damaged. On areas where animals are concentrated, young yellow-poplar is frequently wiped out. Rabbits also eat the bark and buds of seedlings and saplings and can be quite destructive at times.

Because of extremely thin bark, yellow-poplar seedlings and saplings are extremely susceptible to fire damage, and even a light ground fire is usually fatal to stems up to an inch in diameter (*66*). On large trees, which have bark a half inch thick or more, good insulation is provided against all but the hottest fires.

Sleet and glaze storms, which occur periodically within the range of yellow-poplar, may cause considerable damage (*11, 66*). Stump sprouts are particularly susceptible to injury, and slender trees may be broken off. The tops of dominant and codominant trees are often broken, and if breakage is severe the growth rate will be reduced. Top damage is often the point of entry for fungi. Although yellow-poplar usually makes remarkable recovery after such storms, repeated damage can result in a serious growth reduction and loss of quality.

When the sap is running in the spring, yellow-poplar is very susceptible to logging damage. If a falling tree strikes a standing poplar, there is often considerable bark loss up and down the bole of the standing tree. Even if the bark only appears lightly bruised, it may subsequently dry up and fall off in long strips.

Other enemies of this species include grapevines that can reduce growth and sometimes even kill the trees. Japanese honeysuckle can be particularly serious because it thrives on the best sites, smothers small saplings, and precludes regeneration.

Frost, especially in frost pockets, can affect the early growth and development of yellow-poplar. Following a late spring frost in a 20-year-old plantation, it was found that leaf mortality varied from 5 to 100 percent of the leaves on the individual trees (*115*). Leaf mortality was lowest on trees with a high foliar content of potassium. Frost may also cause bole damage in the form of shake, a separation of growth rings resulting in cull. A weather-induced defect called blister shake, related to frost shake, was described in 30-year-old yellow-poplar trees in West Virginia (*103*).

RACES AND HYBRIDS

There are no known natural hybrids of yellow-poplar, but the possible existence of races and geographic strains is being studied (*30, 58, 62, 88*).

A study conducted in the Coastal Plain of South Carolina revealed that yellow-poplar seedlings originating in the North Carolina Coastal Plain were almost twice as high after the third growing season as were seedlings that originated in the mountains of North Carolina (*62*).

Seed from southern latitudes may have a lower germinative capacity and may produce plants that are less frost-hardy than those produced by seed from northern latitudes.

A growth-chamber study revealed that yellow-poplar seedlings of northern and of southern origin responded very differently to day-length treatments. A day-length of 18 hours inhibited the northern but not the southern seedlings (*108*).

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APPENDIX

List of Common and Scientific Names of Trees, Shrubs, and Vines

Common Name	Scientific Name
Ash, white	*Fraxinus americana*
Baldcypress	*Taxodium distichum*
Basswood	*Tilia* sp.
Beech, American	*Fagus grandifolia*
Birch, sweet	*Betula lenta*
yellow	*Betula alleghaniensis*
Blackgum	*Nyssa sylvatica*
Buckeye	*Aesculus* sp.
Cherry, black	*Prunus serotina*
Cucumbertree	*Magnolia acuminata*
Dogwood, flowering	*Cornus florida*
Grapevine	*Vitus* sp.
Hemlock, eastern	*Tsuga canadensis*
Hickories	*Carya* sp.
Honeysuckle, Japanese	*Lonicera japonica*
Locust, black	*Robinia pseudoacacia*
Magnolia, southern	*Magnolia grandiflora*
Maple, red	*Acer rubrum*
sugar	*Acer saccharum*
Oaks	*Quercus* sp.
Oak, black	*Quercus velutina*
cherrybark	*Quercus falcata* var. *pagodaefolia*
chestnut	*Quercus prinus*
northern red	*Quercus rubra*
scarlet	*Quercus coccinea*
southern red	*Quercus falcata* var. *falcata*
swamp chestnut	*Quercus michauxii*
white	*Quercus alba*
Persimmon, common	*Diospyros virginiana*
Pine, eastern white	*Pinus strobus*
loblolly	*Pinus taeda*
pitch	*Pinus rigida*
shortleaf	*Pinus echinata*
Virginia	*Pinus virginiana*
Redcedar, eastern	*Juniperus virginiana*
Sassafras	*Sassafras albidum*
Silverbell, Carolina	*Halesia carolina*
Sourwood	*Oxydendrum arboreum*
Sweetgum	*Liquidambar styraciflua*
Tupelos	*Nyssa* sp.
Walnut, black	*Juglans nigra*
Yellow-poplar	*Liriodendron tulipifera*

List of Common and Scientific Names of Animals and Birds

Common Name	Scientific Name
Cardinal	*Cardinalis cardinalis*
Deer, white-tailed	*Odocoileus virginianus*
Finch, purple	*Carpodacus purpureus*
Mouse, white-footed	*Peromyscus* sp.
Quail	*Colinus virginiana*
Rabbit, cotton-tail	*Sylvilagus floridanus*
Sapsucker	*Sphyrapicus vaius*
Squirrel, gray	*Sciurus carolinensis*
Squirrel, red	*Sciurus hudsonicus*

U.S.D.A. FOREST SERVICE RESEARCH PAPER SE-49

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Effect of Seed Source and Fertilization on Slash Pine Seedling Growth and Development

Forest Service — U. S. Department of Agriculture
Southeastern Forest Experiment Station
Asheville, North Carolina

Effect of Seed Source and Fertilization on Slash Pine Seedling Growth and Development[1]

by

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In recent years fertilization has played an important part in regeneration of certain nutrient-deficient areas of the Southeast. Research has demonstrated that supplemental nutrients applied to low-fertility soils can significantly increase pine production (Walker and Tisdale 1959; Walker 1965). If races or strains of trees exist (or can be developed) which will respond exceptionally well to fertilizers, greater returns may be realized with little additional cost. Recent literature suggests this may be feasible. Nutrient absorption varies between seed sources of *Pinus elliottii* Engelm. (May *et al.* 1962; Walker and Hatcher 1965), *P. banksiana* Lamb. (Giertych and Farrar 1962, Mergen and Worrall 1965), and *P. sylvestris* L. (Steinbeck 1966). Fielding and Brown (1961) found considerable variation in height and diameter growth between 15-year-old clones of *Pinus radiata* D. Don on phosphorus-poor soil in Australia. A strong clone x fertilizer interaction was observed for diameter and height growth in 1-year-old *Populus deltoides* Bartr. var. *deltoides* (Curlin 1967). Seed source x fertilizer interactions were also expressed in height and diameter growth of slash pine progeny lines (Pritchett and Goddard 1967). Some progeny lines made good growth in unfertilized soil, and at the same time responded well to fertilizer treatments.

This paper reports on the development of slash pine seedlings, from several seed sources, grown in a greenhouse under various fertilizer treatments.

MATERIALS AND METHODS

Soil used for the study was from the upper 6 inches of a Bladen fine sandy loam.[2] Soil analysis showed a pH of 4.8, available phosphorus (P) (Bray #2) of 30 pounds per acre, and total nitrogen (N) of 2,080 pounds per acre. Field studies on this soil have resulted in excellent response of slash pine to P or P plus N fertilizers (Pritchett and Llewellyn 1966).

The planting stock consisted of 1-0 slash pine seedlings representing 10 provenances from certain edaphic-climatic zones in Georgia, Florida, and Alabama (fig. 1). A preliminary study of trees grown in nurserybeds indicated that foliage of seedlings from four of these provenances had relatively high P content (.14 percent) and the six surrounding provenances had 7 percent lower foliar P content.[3] The high foliar P seed sources are within or near the region of optimal growth rate in slash pine (Squillace 1966b). Seeds from each provenance were collected from open-pollinated cones of three or more mother trees and sown in the Olustee Experimental Forest nursery in April 1963.

In February 1964, 20 "pretreatment seedlings" from each provenance were taken at random for determination of initial seedling dry weights and mineral nutrient contents. The seedlings were ovendried to a constant weight at 70° C., weighed, ground in a Wiley Mill to pass through

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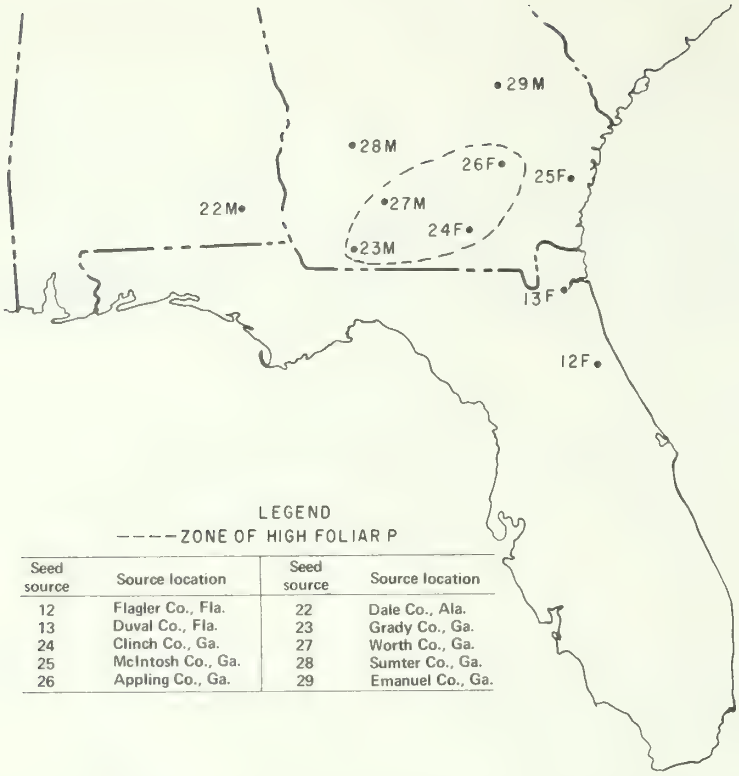
[1] The study was designed and initiated by G. W. Bengtson, formerly employed by this Station.

[2] Topsoil was furnished by Buckeye Cellulose Corporation from Carrabelle, Florida "grass flats" area.

[3] Unpublished data in author's files.



Seed source	Source location	Seed source	Source location
12	Flagler Co., Fla.	22	Dale Co., Ala.
13	Duval Co., Fla.	23	Grady Co., Ga.
24	Clinch Co., Ga.	27	Worth Co., Ga.
25	McIntosh Co., Ga.	28	Sumter Co., Ga.
26	Appling Co., Ga.	29	Emanuel Co., Ga.

Figure 1.—The dots on the map indicate seed source location. Each F indicates a flatwoods source; an M indicates a middle coastal plain source.

a 20-mesh sieve, and thoroughly mixed and subsampled for chemical analyses.

One hundred and twenty seedlings from each provenance were transplanted into 2-gallon ceramic pots—four seedlings in each of 300 pots. The pots were then placed in two greenhouses. The 30 pots from each provenance were randomly divided into six fertilizer treatments each with five replications. Each pot was labeled to show provenance, fertilizer treatment, and replicate.

The fertilizer treatments were:

C—control, no fertilizer.

E—essential nutrients (as recommended for pine by Ingestad 1960) except P, to supply the following per-acre equivalents:

	Lb./A.
Nitrogen (N)	100
Potassium (K)	100
Calcium (Ca)	80
Magnesium (Mg)	30
Sulfur (S)	40
Iron (Fe)	1.86
Manganese (Mn)	0.34
Boron (B)	0.34
Zinc (Zn)	0.04
Copper (Cu)	0.04
Molybdenum (Mo)	0.006

P—ordinary superphosphate (20 percent P_2O_5) to supply 75 pounds of P per acre.

2P—superphosphate to supply 150 pounds of P per acre.

E+P—essential nutrients plus superphosphate to supply 75 pounds of P per acre.

E+2P—essential nutrients plus superphosphate to supply 150 pounds of P per acre.

The fertilizers were applied to the soil surface in each pot. To facilitate movement of P into the soil, distilled water was generously applied to the soil surface. Equal amounts of distilled water were applied to each pot once a week during March and April, and more frequently as the season progressed.

In December 1964, two of the four seedlings in each pot were randomly selected and clipped at the ground line. The secondary needles produced in the first flush of terminal growth of 1964 were ovendried at 70° C., weighed, ground, and subsampled for chemical analyses. The remaining tissue of the two seedlings was also dried and weighed. The two weights were summed to give a measure of relative dry-matter production among treatments and provenances.

In December 1965, the total heights of the two seedlings remaining in each pot were measured and the root systems washed free from soil. Root systems from the seedlings removed in 1964 were relatively small and partially decomposed, making separation from the live roots easy. The two seedlings of each pot were bagged together, ovendried, weighed, ground, and subsampled for chemical analyses.

Total N was determined by macro-Kjeldahl analysis of 1-gram tissue samples. Following dry ashing of 2-gram tissue samples, P was determined by the molybdate-vanadate colorimetric method. K was determined with a Beckman DU flame spectrophotometer.

Dry-weight increment (in milligrams) was determined as the difference in the average dry weight of the 20 pretreatment seedlings per provenance (dried and weighed prior to fertilizer treatments) and average dry weight of seedlings from the same provenances 2 years after treatment. The accumulated weight of each nutrient was obtained by subtracting the weight of each nutrient in the pretreatment seedlings from the weight of the same nutrient in the fertilized and control seedlings after 2 years in pots.

RESULTS AND DISCUSSION

Neither seed source regions (flatwoods or middle coastal plain), nor foliar-P zones, nor zones x regions interaction had any effect on seedling growth (tables 1 and 2). In contrast, the sources within zone-region groups were significantly different, indicating geographic differences without particular pattern.

Growth

Fertilization significantly increased seedling heights (tables 2 and 3). Applying E without P increased heights by 17 percent over unfertilized seedlings. Although P and 2P fertilization significantly increased seedling heights, the data show these fertilizers were effective only when combined with E. Seedlings receiving the E+P and E+2P treatments were significantly taller than all other seedlings and were 36 and 43 percent taller, respectively, than unfertilized seedlings. There was no significant difference between the E+P and E+2P treatments. Seedlings from flatwoods sources with lower foliar P (sources 12, 13, and 25) were shorter than the other source groups and were significantly shorter (8 to 20 percent) than other source groups under the C, E, and E+P fertilization treatments. Squillace (1966a) also noted that slash pine seedlings from coastal sources were shorter than those from inland sources.

Fertilization also significantly increased seedling dry weight increments (tables 2 and 3). As with tree height, the E, E+P, and E+2P treatments affected dry weight increments. Seedlings fertilized with E were more than twice as heavy as unfertilized controls, and those fertilized with E+P or E+2P were nearly four times heavier than unfertilized seedlings. The average dry weight increment of middle coastal plain seedlings was 23 percent greater than that of flatwoods seedlings under the E fertilization treatment. This difference was highly significant.

As with height and total dry weight increments, the E, E+P, and E+2P treatments significantly increased shoot and root weights, and shoot/root ratios (tables 2 and 3). The average weights of seedlings from these treatments were two to four times greater than the unfertilized controls. The interaction of region x fertilization significantly affected both shoot and root weights 2 years after treatment. As with total dry weight increment, this was the result of large differences between seed sources in the E treatment only. Middle coastal plain seedlings had 21 percent heavier shoots and 31 percent heavier roots than did the flatwoods seedlings. This suggests that, as long as other elements are not limiting, middle coastal plain seedlings grow more rapidly than flatwoods seedlings under relatively low available P.

Limited growth responses to fertilizers other than N and P have been obtained in the flatwoods (Pritchett 1963). Data in this study show that all measures of growth were greatly stimulated by E fertilization, but the combination of E with P or 2P produced the best growth. These results suggested that N may have been the most limiting factor in this soil under conditions imposed in the greenhouse. In contrast, field results on similar soil indicated that P was the primary limiting factor, and that P+N resulted in the greatest total growth (Pritchett and Swinford 1961; Pritchett 1963). Soil P apparently was not limiting in this study until available N was increased. Differences in results of this study and field experiments may be accounted for by (1) the removal of much organic debris in the potted soil, (2) a competition-free environment in the greenhouse enabling seedlings to utilize fully the added N, and (3) the probability of a slightly different soil.

Table 1.—Growth and nutrient accumulation in slash pine seedlings 1 and 2 years after fertilization

Geographic seed source[1]	1 Year				2 Years										
	Avg. shoot weight	N in foliage	P in foliage	K in foliage	Avg. tree height	Seedling dry weight increments	Avg. shoot weight	Avg. root weight	Shoot/root ratio	N in total plant	P in total plant	K in total plant	N accumulated	P accumulated	K accumulated
	Grams	- - - *Percent* - - -			*Centimeters*	- - - *Grams* - - -				- - - *Percent* - - -			*Milligrams per seedling*		
12	12.0	0.70	0.08	0.25	55.7	40.7	34.3	9.0	3.5	0.42	0.08	0.17	160	31	67
13	12.8	0.72	0.08	0.27	57.7	37.0	31.5	9.2	3.3	0.42	0.08	0.16	147	27	51
24	11.9	0.77	0.08	0.30	65.2	39.0	33.7	9.3	3.6	0.45	0.09	0.16	167	29	55
25	13.0	0.74	0.08	0.22	60.2	41.2	32.9	10.9	3.0	0.44	0.08	0.13	165	30	46
26	11.0	0.72	0.08	0.29	60.9	37.9	31.6	8.7	3.4	0.44	0.09	0.17	154	30	54
22	13.3	0.76	0.08	0.23	65.4	43.8	35.5	11.4	3.0	0.41	0.08	0.14	173	30	55
23	11.8	0.72	0.08	0.26	62.2	37.9	31.6	9.7	3.1	0.44	0.08	0.15	158	28	52
27	11.1	0.72	0.08	0.26	64.0	40.6	34.2	9.2	3.6	0.42	0.08	0.16	163	28	61
28	13.2	0.67	0.07	0.26	68.0	38.8	32.3	10.1	3.0	0.39	0.08	0.14	147	27	48
29	10.2	0.72	0.09	0.30	58.2	38.6	32.0	9.3	3.4	0.45	0.09	0.18	172	30	64
Average	12.0	0.72	0.08	0.26	61.8	39.5	33.0	9.7	3.3	0.43	0.08	0.16	161	29	55

[1] Numbers refer to map locations, figure 1.

Table 2.—Analyses of variance of growth 2 years after fertilization

Source of variation	d.f.	Tree height	Dry weight increment	Total shoot weight[1]	Total shoot weight	Total root weight	Shoot/root ratio
		- - - - - - - - *Mean squares* - - - - - - - -					
Sources (S)	9						
Zones (Z)	1	352.45	94.65	267.19	32.76	174.80	3.60
Regions (R)	1	966.61	44.74	12.73	37.69	87.04	1.79
Z x R	1	641.42	0.09	8.42	1.21	0.90	0.00
Sources within ZR Groups (G)	6	362.71**	160.88*	151.48*	342.64	98.91**	1.65**
Fertilization (F)	5						
Phosphorus (P)	2	1,513.20**	5,906.49**	976.81**	15,799.75**	787.11**	0.92
Essential elements (E)	1	21,193.21**	132,163.54**	23,123.01**	345,391.11**	19,430.93**	56.29**
P x E	2	1,163.58**	6,361.85**	565.81**	16,515.49**	978.46**	1.09
S x F	45						
Z x F	5	71.36	91.42	21.18	170.48	42.86	0.27
R x F	5	73.13	274.78**	57.19	565.14*	88.95**	0.08
Z x R x F	5	155.62**	93.81	88.78*	296.20	7.27	0.59
G x F	30	23.00	77.70	29.55	253.28	18.51	0.56
Within-cell variation	240	46.18	74.00	35.06	202.91	22.34	0.44
Total	299						

[1] One year after fertilization.
*Significant at the 5-percent level.
**Significant at the 1-percent level.

Table 3.—Slash pine seedling growth 2 years after fertilization[1]

Fertilization treatment[2]	Tree height	Seedling dry weight increments	Avg. shoot weight[3]	Avg. shoot weight	Avg. root weight	Shoot/root ratio
	Centimeters		- - - - - - - - - - - *Grams* - - - - - - - - - - - - -			
C	53.1	19.0	7.2	16.3	5.9	2.9
P	52.5	17.5	7.9	15.3	5.3	2.9
2P	54.5	19.2	7.7	16.4	5.8	2.8
E	62.1	42.6	13.4	35.4	10.3	3.5
E+P	72.2	67.3	18.8	55.2	15.3	3.7
E+2P	76.2	71.6	17.1	59.2	15.6	3.9
Mean	61.8	39.5	12.0	33.0	9.7	3.3

[1] Each number is an average of 50 seedlings.

[2] Symbols refer to: untreated control (C), 75 pounds of phosphorus per acre (P), 150 pounds of phosphorus per acre (2P), essential nutrients except phosphorus (E), essential nutrients + 75 pounds of phosphorus per acre (E+P), essential nutrients + 150 pounds of phosphorus per acre (E+2P).

[3] One year after fertilization.

Nutrient Accumulation

The regions, zones, and regions x zones interactions had no effect on either the nutrient content or the nutrient accumulation of the seedlings. However, the amounts of N, P, and K in the seedling were significantly related to the fertilization treatments (tables 4, 5, and 6). Weights of accumulated nutrients showed the most striking differences. The total amounts of N and K accumulated were four times greater with E fertilization than with no fertilization, and P accumulation was four times greater with P or 2P fertilization than with no fertilization. In addition, the accumulated P was three times greater with E+P or E+2P than with P or 2P fertilization. This further suggests that some element other than P was the most limiting under conditions of this experiment.

Nutrient concentrations in the foliage were directly related to the type of fertilizer applied. After 1 year the average concentrations of N and K in the foliage of seedlings fertilized with E were 91 and 19 percent higher, respectively, than in the unfertilized seedlings. The average P content of seedlings fertilized with P or 2P was 67 percent higher than in the unfertilized seedlings. Similarly, after 2 years the concentrations of each element in the total plant tissue were directly related to the fertilizer applied.

The significant P x E interactions for N and K contents, 1 and 2 years after treatment, probably were the result of negative correlations of both N and K with P (tables 4 and 5). Where all essential elements except P were added to the soil, N and K concentrations in the foliage and total plant tissue were highest. When P was added in combination with E, the N and K contents decreased. In addition, unfertilized seedlings had higher amounts and concentrations of N than did seedlings fertilized with P or 2P. Such antagonistic correlations of N and K in relation to P have been noted in many plants (Cain 1959; Emmert 1960).

Source x fertilization interactions significantly affected the amount of N in the seedlings. The zones x fertilization interactions for percent N, 1 and 2 years after treatment, were significant primarily because 20 percent more N was found in unfertilized seedlings from the zone of high foliar P than in unfertilized seedlings from the zone of lower foliar P. The significant region x fertilization difference in percentage N in total plant tissue, with E fertilization, was probably the result of flatwoods seedlings having 12 percent higher N content than middle coastal plain seedlings.

The zone x region x fertilization interaction showed significant differences for percentage P and K in total plant tissue (table 5). The data did not show clear reasons for these significant differences. However, in each case flatwoods trees from the zone of lower foliar P showed lower nutrient contents when unfertilized than did the other seed sources.

Table 4.—Effects of fertilization on nutrient accumulation in slash pine seedlings 1 and 2 years after treatment

Fertilization treatment[1]	1 Year			2 Years					
	N in foliage	P in foliage	K in foliage	N in total plant	P in total plant	K in total plant	N accumulated	P accumulated	K accumulated
		Percent			Percent			Milligrams per seedling	
C	0.58	0.06	0.26	0.42	0.04	0.15	68	4	21
P	0.53	0.09	0.26	0.33	0.11	0.14	42	16	18
2P	0.56	0.11	0.25	0.33	0.12	0.14	49	21	20
E	1.11	0.05	0.31	0.70	0.04	0.23	292	14	94
E+P	0.79	0.08	0.23	0.39	0.08	0.14	251	52	85
E+2P	0.78	0.09	0.28	0.39	0.10	0.14	263	67	94
Mean	0.72	0.08	0.26	0.43	0.08	0.16	161	29	55

[1] Symbols refer to untreated control (C), 75 pounds of phosphorus per acre (P), 150 pounds of phosphorus per acre (2P), essential nutrients except phosphorus (E), essential nutrients + 75 pounds of phosphorus per acre (E+P), essential nutrients + 150 pounds of phosphorus per acre (E+2P).

Table 5.—Analyses of variance of nutrient content[1]

Source of variation	d.f.		Percent nutrients in foliage 1 year after fertilization			Percent nutrients in total plant tissue 2 years after fertilization		
			N	P	K	N	P	K
					Mean squares			
Sources (S)	9							
Zones (Z)		1	1.32	0.01	3.52	2.38	3.86	0.55
Regions (R)		1	1.39	0.01	0.01	1.02	3.65	0.04
Z x R		1	0.94	0.00	4.84	0.13	0.37	0.05
Sources within ZR Groups (G) (Error A)		6	3.17	0.04	1.93*	1.29*	3.37*	1.36**
Fertilization (F)	5							
Phosphorus (P)		2	105.85**	4.81**	3.27**	135.81**	1,200.28**	8.04**
Essential elements (E)		1	862.25**	0.48**	2.74**	130.02**	216.24**	5.07**
P x E		2	70.36**	0.05	3.51**	40.06**	49.83**	6.43**
S x F	45							
Z x F		5	3.69*	0.03	1.66	1.74*	1.43	0.71
R x F		5	0.76	0.02	0.23	1.34*	1.42	0.08
Z x R x F		5	1.34	0.01	1.68	0.83	10.54**	1.11*
G x F		30	1.60	0.03	0.77	0.91*	0.45	0.20
Within-cell variation (Error B)	240		1.66	0.02	0.86	0.58	1.30	0.41
Total	299							

[1] Coded x 100.
*Significant at the 5-percent level.
**Significant at the 1-percent level.

Table 6.—Analyses of variance of nutrient accumulation

Source of variation	d.f.		Nutrients (mg.) accumulated 2 years after fertilization		
			N	P	K
			- - - - - - Mean squares - - - - -		
Sources (S)	9				
Zones (Z)		1	0.11	1.99	6.80
Regions (R)		1	237.80	4.94	28.34
Z x R		1	156.82	5.68	5.29
Sources within ZR Groups (G)		6	713.37	17.82	431.24**
Fertilization (F)	5				
Phosphorus (P)		2	6,078.24**	6,523.55*	226.18
Essential elements (E)		1	697,714.02**	13,983.35**	75,809.66**
P x E		2	260.33	1,675.58**	90.01
S x F	45		423.33	11.99	115.97
Total	59				

*Significant at the 5-percent level.
**Significant at the 1-percent level.

CONCLUSIONS

The ability of slash pine to absorb nutrients and grow varies by seed source. Significant fertilization x seed source interactions occurred for all growth traits and most nutrient traits analyzed. Seedlings from the zone of high foliar P absorbed more N and K when unfertilized, but did not grow more rapidly than seedlings from other sources. Middle coastal plain seedlings grew much better than flatwoods seedlings when fertilized with all essential elements except P. This suggests that seedlings from the middle coastal plain can grow rapidly under conditions of low available P. Overall results indicate that seedlings from coastal sources (12, 13, and 25) grew slowest, and that high foliar P is not necessarily associated with a potential for more rapid growth in slash pine.

Seedlings fertilized only with P or 2P were no larger than the controls. Seedling size was significantly increased by E fertilization, but the E+P or E+2P treatments resulted in greatest growth increase. In light of past fertilization results in the flatwoods, these data suggest that best growth resulted from an N+P fertilization, with N as the primary limiting factor.

Nutrient accumulation closely followed the type of fertilizer applied, except that P fertilization negatively affected the levels of N and K. The total amounts of N, P, and K accumulated under high fertilization treatments suggest that growth differences between fertilized and unfertilized trees would continue.

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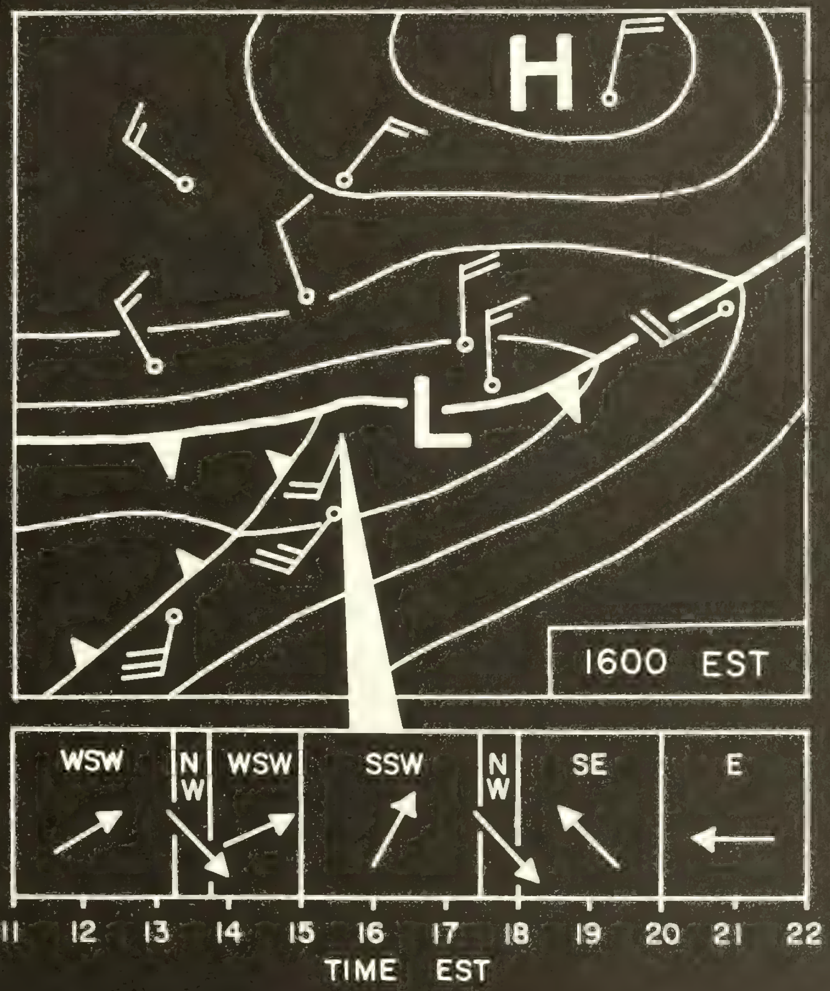
UNUSUAL WIND SHIFTS OF TWO WILDFIRES



Forest Service - U. S. Department of Agriculture
Southeastern Forest Experiment Station - Asheville, North Carolina

Unusual Wind Shifts of Two Wildfires

by
Dansy T. Williams, Principal Meteorologist
Southern Forest Fire Laboratory
Macon, Georgia

INTRODUCTION

In flat terrain the control tactics for a wildfire are determined to a large extent by the direction and speed of the surface wind. Changes in the wind, especially unexpected changes in its direction, may present severe control problems.

In April 1966, two wildfires occurred in coastal North Carolina in which multiple and seemingly capricious changes in wind direction occurred. In both fires, control was impaired and comparatively large acreages were burned. A piece of equipment was lost in one fire, and the lives of a crew were endangered.

The changes in wind in the Air Force Range Fire were due to the oscillatory passage of a sea breeze front. In the Holly Shelter Fire they were due to passages of a pressure trough line and a sea breeze front and the partial passage, retreat, and final passage of a surface cold front. It is the purpose of this paper to describe these events and their relationships to the behavior of the fires.

THE AIR FORCE RANGE FIRE

Features of the Fire

The fire occurred on a bombing range in Dare County, North Carolina. Most of Dare County is a small peninsula of low, flat terrain in the coastal area of the state. Except for a land connection to the southwest it is surrounded by sounds, and the Atlantic Ocean lies 10 to 15 miles further east. The fire site was nearly in the center of the peninsula, being approximately 8 miles from water to the east, 6 miles from water to the west, 15 miles from water to the north, and 11 miles from water to the south. The proximity of water bodies, including the Atlantic Ocean, suggests that the shifts in the wind may have resulted from passages of a sea breeze front.

The fire began during the morning of April 11, 1966. By the time it was controlled early the next morning, 3,755 acres had been burned (fig. 1), including 2,800 acres of commercial timber belonging to the West Virginia Pulp and Paper Company. Fuel was primarily gallberry and pond pine, with a concentration of 15 to 20 tons of dry fuel per acre.

In its early stages the fire was under the influence of a west to west-southwest wind. Dur-

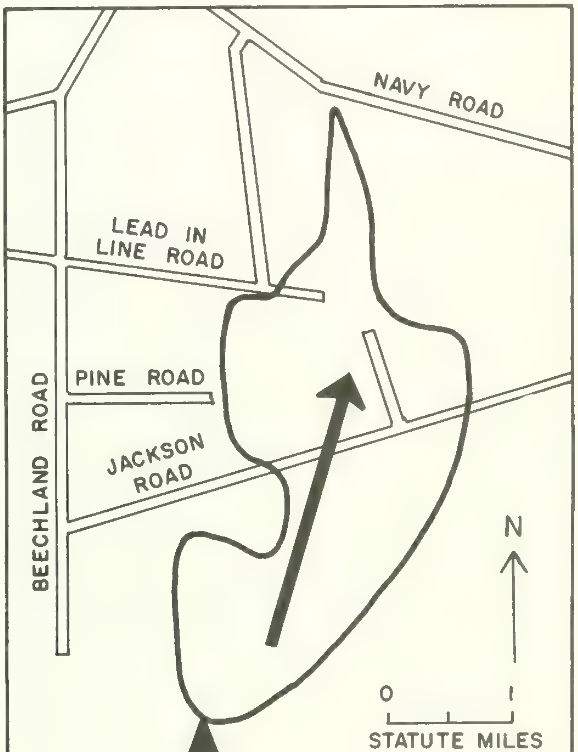


Figure 1.—Site of the Air Force Range Fire. The area burned is outlined, and the major roads are shown. The solid black triangle in this and three subsequent figures indicates the fire's point of origin.

ACKNOWLEDGMENTS
The author is indebted to Mr. Fred H. Claridge, then State Forester; Mr. Henry S. Plotkin, Staff Forester (District Operations); and other personnel of the North Carolina Department of Conservation and Development, Division of Forestry, for suggesting this study and for providing the factual information on the two fires.

ing this time crews were to the east and northeast of the fire and were using backfires as control measures.

At about 1220 EST the wind shifted from west to east, turning through north in making the shift. The southern flank of the fire built up briefly while the wind was from the north, but with the easterly wind the main head had to burn as a backfire, and control seemed assured.

The wind held from the east for only about 10 minutes, shifting then to south at about 1230 EST and to south-southwest shortly thereafter. This shift caused the fire to advance rapidly on its northern flank, trapping a crew. The crew included three men with a "Bombardier" (a lightweight tracked vehicle with tanks and pumps) and one man on foot. The men were able to escape, but the "Bombardier" was lost.

The wind continued from the south-southwest for several hours after 1230 EST with increasing speed. By 1300 EST the fire was characterized on its northern head by high intensity, rapid spread, spotting, and convection columns. The major run of the fire, shown by the heavy arrow in figure 1, occurred during the early and middle afternoon, but running and spotting continued to the north and northeast during the late afternoon and evening.

Later in the evening the wind shifted to easterly, causing the western flank of the fire to turn into a westward-moving head between Lead In Line Road and Jackson Road at about 2000 EST. Scattered light drizzle began at about 2100 EST, and by daylight the next morning the fire was controlled.

Surface Weather Features

Sectional surface synoptic charts of southeastern Virginia and eastern North Carolina for 1000, 1300, and 1600 EST, April 11, 1966, are shown in figures 2 through 4. A sea breeze front was present and is shown by the line along the coast. Cold front symbols (triangles) are used to show the general motion of the front from the sea (colder area) toward the land (warmer area). A warm front was also present and is indicated by the heavy line with warm-front symbols (semicircles) in the left portion of the figures. The warm front did not pass the fire site and was not involved in the wind shifts. However, its presence was responsible for the drizzle which began late in the evening.

One may note in figures 2 through 4 the general motion of the sea breeze front from sea to land and its effect in shifting the winds at coastal stations. It was analyzed to be east of the fire site on the three charts; but, as will be described later, it apparently made an oscillatory passage over the fire site at about 1220 EST. Analyzed charts for times after 1600 EST (not shown) indicated continued westward movement of the sea breeze front; consequently it would have passed the fire site shortly after 1600 EST. This passage would have resulted in a shift in the wind from south-southwest to south-southeast or southeast. Such a shift was not specifically reported by the firefighting crews, although they did report a shift to "easterly" at about 2000 EST.

One may note the dryness of the airmasses, shown by the plotted temperatures and dewpoints in figures 2 through 4. On the land side of the sea breeze front, coastal stations had dewpoints in the high 20's and low 30's. Corresponding relative humidities were generally from 30 to 35 percent. Although not so extreme, dry air

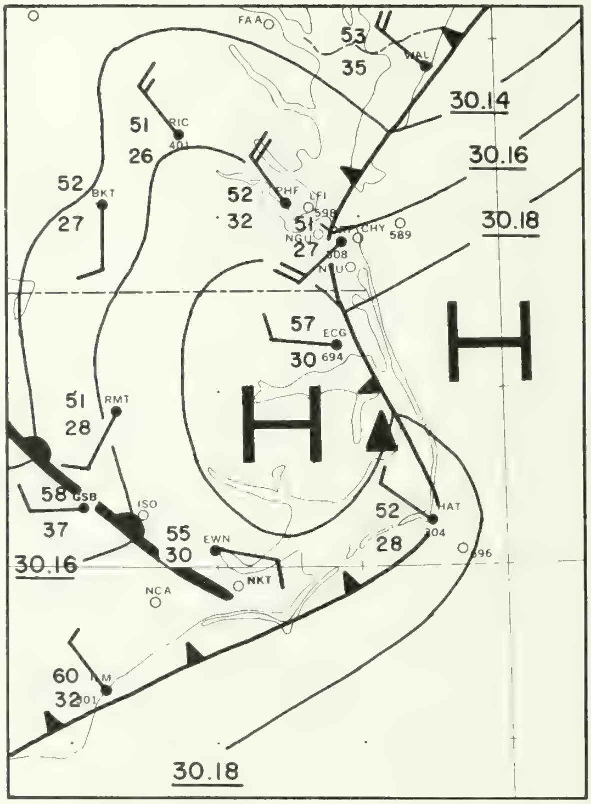


Figure 2.—Sectional surface synoptic chart for 1000 EST, April 11, 1966. Arrows follow the wind. Barbs indicate wind speed, with a whole barb equal to 5 knots and half a barb equal to 2-3 knots. Temperature and dewpoint values are plotted in degrees F. Isobars are drawn for each 0.02 inch of mercury, and high-pressure centers are indicated by an "H."

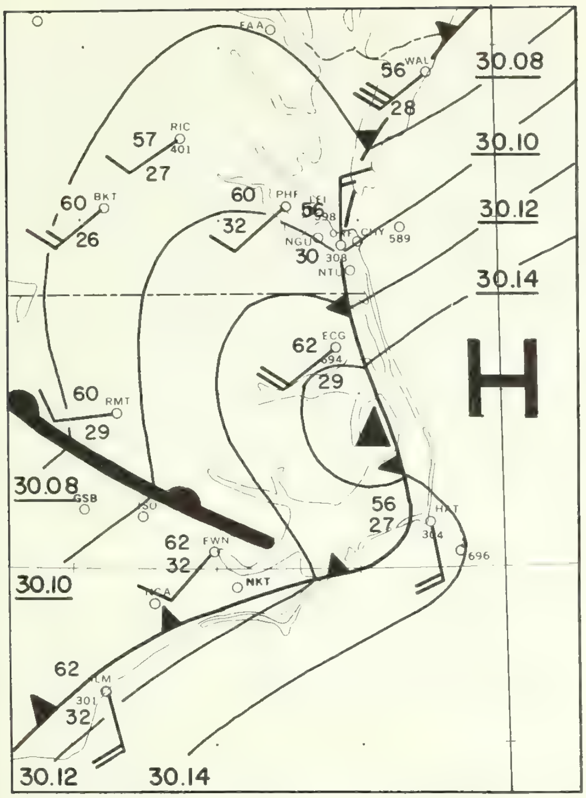


Figure 3.—Sectional surface synoptic chart for 1300 EST, April 11, 1966.

was present on the sea side of the front, too. At 1600 EST coastal stations had dewpoints generally in the middle 30's with relative humidities near 40 percent. The dryness of the airmass produced conditions rated in the higher categories of fire danger and contributed to the intensity and rapid spread of the fire.

Airmasses over the sea are typically moist at the surface. The anomalous dryness in this case was due to the origin and trajectory of the airmass involved. On the previous day, a dry airmass of polar continental origin was centered in the lower Ohio River Valley and covered the eastern portion of the United States. On the day of the fire a portion of this airmass had moved eastward to just off the coast of North Carolina (*1*). Because its existence over water was thus too brief to permit much evaporation from the water, its moisture content was only slightly more than that of the airmass over land.

Normally, the movement of a continental airmass from land to sea destroys the sea breeze front temporarily. This case was unusual in that the destruction either did not occur or the sea breeze front was regenerated more rapidly than might have been expected. It appears that a partial separation of the airmass remaining over land from the airmass over the sea permitted a rapid formation of the sea breeze front in the zone between them. As pointed out by Fosberg and Schroeder (*2*), the sea breeze front is primarily a wind shift line, and temperature and moisture discontinuities may lag behind it.

Sea Breeze Features at Elizabeth City and Hatteras

Elizabeth City and Hatteras (ECG and HAT in figs. 2 through 4) were the nearest hourly reporting weather stations to the fire site. The site is approximately on a line and midway between these two stations, Elizabeth City being about 40 miles to the north-northwest and Hatteras being about 40 miles to the south-southeast. Something of the motion of the sea breeze front may be learned by detailed analyses of these hourly observations.

Hourly histories of surface features associated with the sea breeze from 0800 to 1800 EST for Elizabeth City and Hatteras are shown in figures 5 and 6. Temperature is the upper trace, dewpoint is the middle trace, and relative

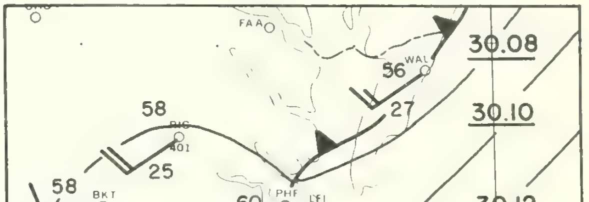


Figure 4.—Sectional surface synoptic chart for 1600 EST, April 11, 1966.

humidity is the lower trace. Winds are plotted in the same manner as in figures 2 through 4. Complete passages of the sea breeze front are shown by solid vertical lines; partial passages are shown by open vertical lines. Cold-front symbols (triangles) are used to indicate a passage from sea to land; warm-front symbols (semicircles) are used to indicate a passage from land to sea.

In general, complete passages of the sea breeze front are indicated by substantial shifts in wind direction. A passage from sea to land is usually accompanied also by a fall in temperature, a rise in dewpoint, and a rise in relative humidity. The reverse is usually true for a passage from land to sea. Partial passages of the sea breeze front are indicated by lesser changes in wind direction, by changes in wind speed, and by accompanying changes in temperature, dewpoint, and relative humidity.

The hourly history for Elizabeth City (fig. 5) shows a complete passage of the front from sea to land between 1000 and 1100 EST, a complete passage from land to sea between 1200 and 1300 EST, and a final complete passage from sea to land between 1500 and 1600 EST. The three passages are well defined; and, since only one front was involved, it is apparent that the motion of the front was oscillatory in the vicinity of Elizabeth City.

The hourly history for Hatteras (fig. 6) shows five passages of the sea breeze front. There was a partial passage from sea to land between 0900 and 1000 EST, followed by a retreat from land to sea again between 1000 and 1100 EST. A complete passage from sea to land then occurred between 1200 and 1300 EST. From 1400 to 1500 EST, however, there was a partial retreat from land to sea, followed during the next hour by a resumption of its motion from sea to land. Since only one front was involved, it is apparent that the one complete and four partial passages at Hatteras were due to the oscillatory motion of the sea breeze front.

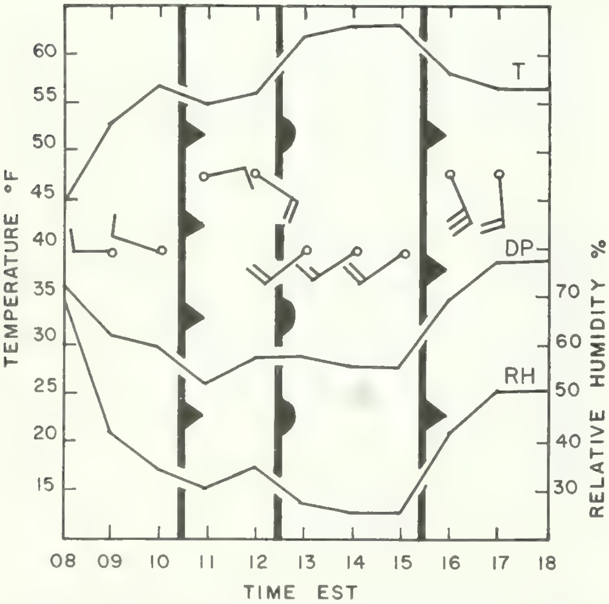


Figure 5.—Hourly history of temperature, wind, dewpoint, relative humidity, and passages of the sea breeze front at Elizabeth City from 0800 to 1800 EST, April 11, 1966.

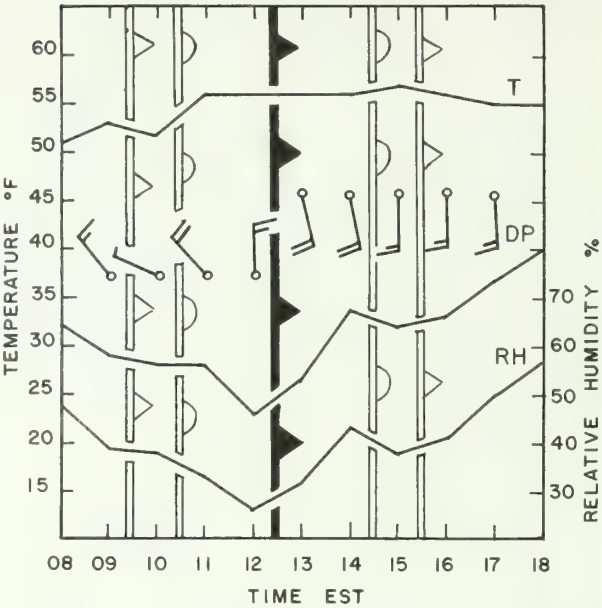


Figure 6.—Hourly history of temperature, wind, dewpoint, relative humidity, and passages of the sea breeze front at Hatteras from 0800 to 1800 EST, April 11, 1966.

Discussion

Data are lacking to establish a complete time history of weather events at the fire site, but reports of the fire-fighting crews indicate this sequence: (1) Passage of the sea breeze front from sea to land at about 1220 EST, shifting the wind from west through north to east, (2) partial retreat of the front from land to sea at about 1230 EST with the wind shifting from east to south and then to south-southwest, and (3) final passage of the front from sea to land after 1600 EST with the winds definitely easterly by 2000 EST. The behavior of the winds at the fire site indicates an oscillatory motion of the sea breeze front similar to those at Elizabeth City and Hatteras.

Oscillatory motions of a sea breeze front are not unusual. Properties of the sea breeze front have been documented by a small-scale research network of surface weather stations on the Harris Neck Wildlife Refuge in coastal Georgia.[1] Sea breeze fronts passed the network on 92 days during the 9-month period from March 1 to November 30, 1967, and oscillatory passages occurred on approximately one-third of these days.

The data acquired from the Harris Neck network also indicate that passages of the sea breeze front and its potential for influencing fire behavior can be forecast. In addition, knowledge of its properties can be used directly by fire control personnel in modifying control tactics, should an unexpected passage occur.

THE HOLLY SHELTER FIRE

Features of the Fire

The fire occurred in southeastern North Carolina in an area approximately 30 miles north of Wilmington and 19 miles from the coast of the Atlantic Ocean. The terrain is low and flat.

The fire began at about 1100 EST on April 25, 1966. By the time it was controlled late that night, over 4,000 acres of timbered land had been burned (fig. 7). Fuels were primarily gallberry, redbay, swamp cyrilla, and fetterbush, with concentrations of 15 to 25 tons per acre.

The fire was unusual because of the numerous shifts in wind direction that occurred during its progress. In the 10-hour period from 1100 to 2100 EST, six changes in wind direction occurred, and during one period winds from opposing directions prevailed in different portions of the fire. Observed wind directions are shown by the numbered arrows in figure 7, and times of the various shifts are shown on the cover diagram.

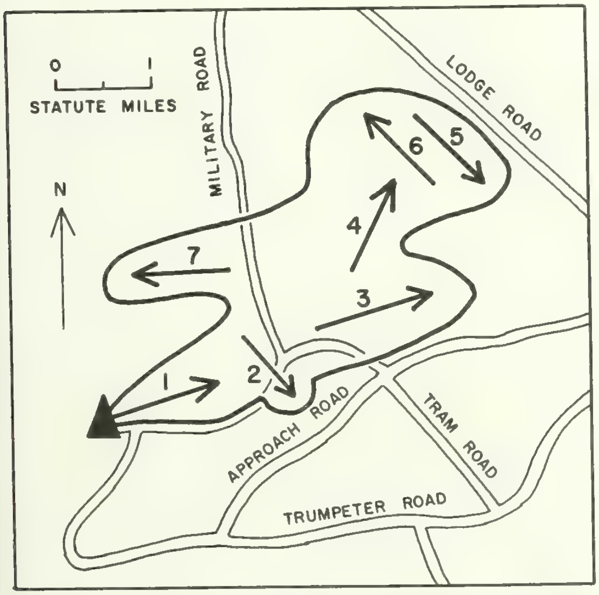


Figure 7.—Site of the Holly Shelter Fire. The area burned is outlined, and the major roads are shown. The solid black triangle in this and subsequent figures indicates the fire's point of origin.

The fire began at about 1100 EST and burned with a west-southwest wind until 1315 EST, as shown by arrow 1. At 1315 EST the wind shifted to northwest, as shown by arrow 2, returning to west-southwest again at 1345 EST, as shown by arrow 3. From 1345 to 1500 EST this wind prevailed, and the fire burned with a hot but steady head to the east-northeast.

At 1500 EST the wind shifted to south-southwest, as shown by arrow 4, making a head of the northern flank. This head was active until 1730 EST and was characterized by crowning and spotting to the north-northeast. Several spots crossed Lodge Road, but the main head did not.

At 1730 EST the wind shifted to northwest, as shown by arrow 5, making a head of the southeastern flank. With the northwest wind the fire advanced to the southeast, paralleling Lodge Road. A shift in the wind did not occur at the southwest extremity of fire; this extremity continued to burn with a south-southwest wind.

At 1800 EST wind speed diminished and calm conditions prevailed for a 5-minute period. At 1805 EST the wind picked up from the southeast, as shown by arrow 6, making a head of the northwest flank. The fire progressed northwestward and then westward with the wind from the east, as shown by arrow 7, until the fire was put out by rain later in the night.

The six shifts in wind direction during the course of the fire presented extreme control problems and were the major reasons for the extent of the fire.

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[1] Williams, D. T. Fire behavior and the sea breeze front. Presented at the American Meteorological Society-Society of American Foresters Conference on Fire and Forest Meteorology, Salt Lake City, Utah, March 12-14, 1968. (Unpublished, 12 pp. and 20 figs.)

Surface Weather Features

Sectional surface synoptic charts for selected times are shown in figures 8 through 14. The sections cover central and eastern portions of North Carolina and a small portion of eastern South Carolina. The charts are for 1000, 1330, 1430, 1600, 1800, 1900, and 2100 EST and show the seven wind regimes that occurred at the fire site. The wind regimes were as follows:

1000-1315 EST.—Wind was from the west-southwest, as shown by arrow 1 in figure 7, and was influenced by the pressure trough line (heavy dashed line) shown by the chart for 1000 EST in figure 8.

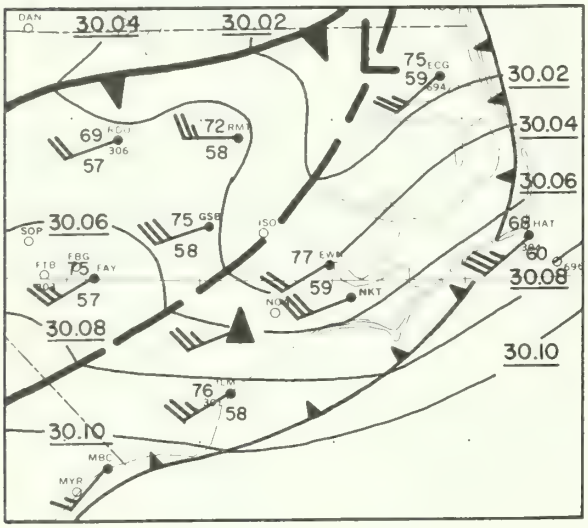

Figure 8.—Sectional surface synoptic chart for 1000 EST, April 25, 1966. A low-pressure center is indicated by an "L."

1315-1345 EST.—Wind was from the northwest, as shown by arrow 2 in figure 7 and by the chart for 1330 EST in figure 9. Although the wind conformed to the pressure field behind the pressure trough line, the shift did not occur until about 2 hours after the line had passed. The trough line is not shown at 1330 EST; by this time the sea breeze front (light solid line with cold front symbols) had moved northwestward into the trough.

1345-1500 EST.—Wind was from the west-southwest again, as shown by arrow 3 in figure 7 and by the chart for 1430 EST in figure 10. There does not appear to have been a sufficient change in the pressure field to have shifted the wind, but the shift may have resulted from the approach of the cold front (heavy solid line with cold front symbols) to the north.

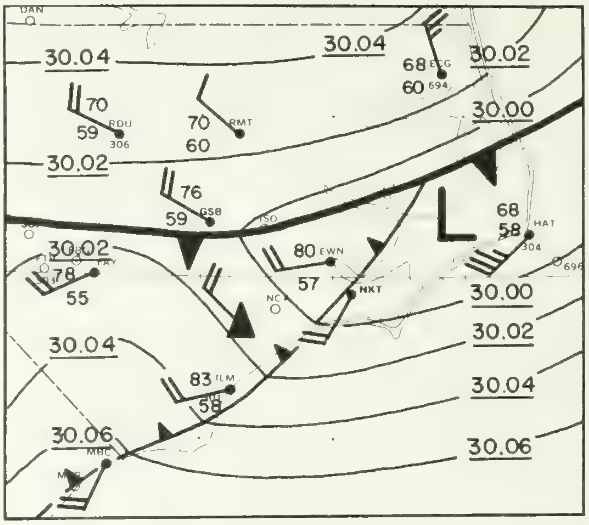

Figure 9.—Sectional surface synoptic chart for 1330 EST, April 25, 1966, interpolated from analyses of 1300 and 1400 EST data.

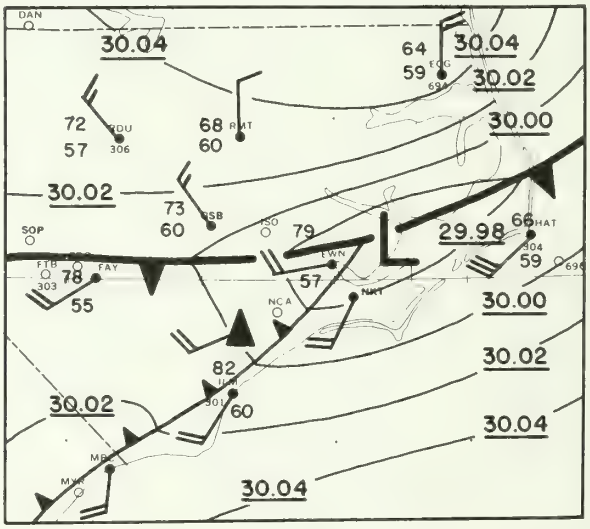

Figure 10.—Sectional surface synoptic chart for 1430 EST, April 25, 1966, interpolated from analyses of 1400 and 1500 EST data.

1500-1730 EST.—Wind was from the south-southwest, as shown by arrow 4 in figure 7 and by the chart for 1600 EST in figure 11 and in the cover diagram. The shift occurred when the sea breeze front passed from southeast to northwest.

1730-1800 EST.—Wind was from the northwest in the northern portion of the fire, as shown by arrow 5 in figure 7, and remained from the south-southwest in the southwest portion. This difference was due to the partial passage of the cold front, as shown by the chart for 1800 EST in figure 12.

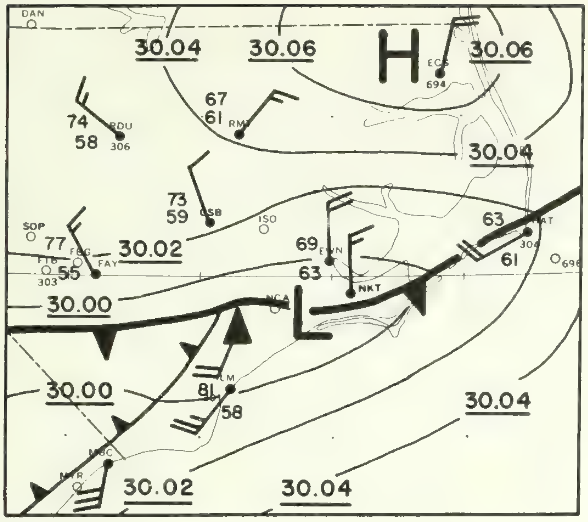

Figure 11.—Sectional surface synoptic chart for 1600 EST, April 25, 1966.

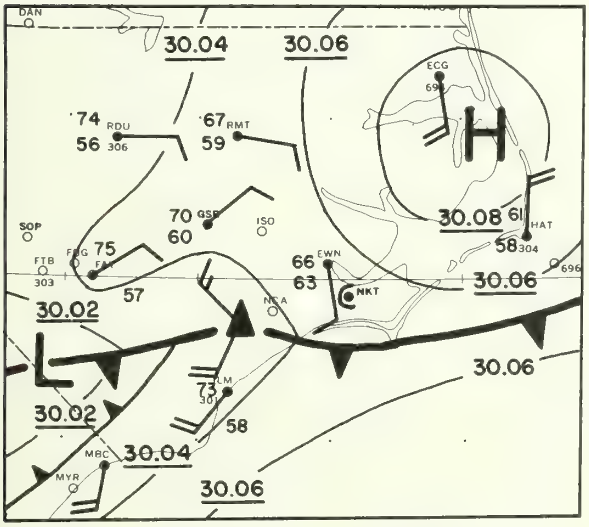

Figure 12.—Sectional surface synoptic chart for 1800 EST, April 25, 1966. Note the two wind directions at the fire site.

1800-1805 EST.—Calm winds prevailed briefly due to a complete stalling of the cold front.

1805-2000 EST.—Wind was from the southeast, as shown by arrow 6 in figure 7 and by the chart for 1900 EST in figure 13. The shift was due to the formation and northward retreat of a wave on the cold front.

2000-2200 EST.—Wind was from the east, as shown by arrow 7 in figure 7 and by the chart for 2100 EST in figure 14. The shift occurred with the second and complete passage of the cold front. The shift this time was to easterly rather than northwesterly because of the presence of the wave on the front.

The air was not unusually dry, as may be noted by the plotted temperatures and dewpoints in figures 8 through 14. Relative humidities in the vicinity of the fire site were near 55 percent at 1000 EST, down to about 45 percent at 1330, 1430, and 1600 EST, and rose thereafter. Although relative humidities were certainly low enough to support burning, they were not critically low, indicating that the unusual behavior of the fire was due to other causes, such as the shifts in wind direction.

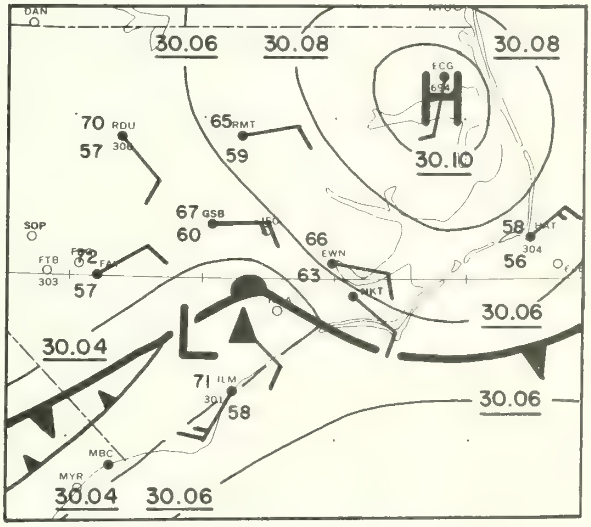

Figure 13.—Sectional surface synoptic chart for 1900 EST, April 25, 1966.

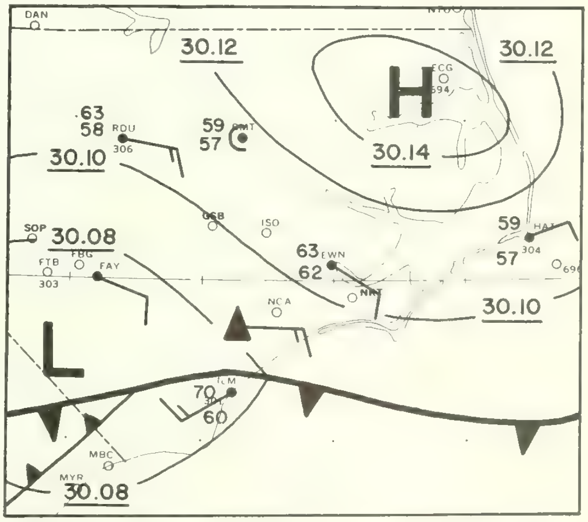

Figure 14.—Sectional surface synoptic chart for 2100 EST, April 25, 1966.

Discussion

The pressure trough line was fairly typical of small-scale patterns that may be present in warm airmasses ahead of surface cold fronts. A similar pressure trough line was present near the Hellgate Fire (*3*). Wind shifts associated with such troughs may be slight and brief. In the Holly Shelter Fire the shift was from west-southwest to northwest and lasted for only 30 minutes.

The sea breeze front is a typical feature of coastal areas. Although its influence on the Holly Shelter Fire was limited to one wind shift, it was the major synoptic feature of the previously described Air Force Range Fire.

The behavior of the surface cold front in the vicinity of the Holly Shelter Fire is of special interest. Although wave formations and local oscillations are fairly common features of frontal motions, it is a remarkable coincidence that this wave motion occurred precisely over the fire site. This behavior may have been induced by the fire itself.

A cold front is a wedge of cooler air which advances and displaces the warmer air ahead of its shallow leading edge. Large quantities of heat produced by the fire and released locally at the advancing edge of the cooler air would warm it, destroying the frontal boundary there and establishing a new boundary a short distance to the north. Surface winds would then conform to the new frontal boundary. This condition would prevail until the heat of the fire had diminished or until a sufficient depth of cold air had accumulated to overwhelm the heat of the fire. The evidence in the Holly Shelter Fire is circumstantial but does suggest that the fire itself was a modifying mechanism that contributed to the behavior of the front.

The proximity of three mechanisms (pressure trough, sea breeze front, and surface cold front) and their combined effects in causing six shifts in wind direction appear so unusual as to have little chance of occurring again. However, in view of the frequent presence of trough lines in warm airmasses ahead of cold fronts and the frequent occurrence of sea breeze fronts in coastal areas, one might expect similar effects on coastal winds whenever a frontal system approaches. Although detailed forecasts of individual wind shifts may never be possible, advance warnings of the potential for such wind shifts could be made; and fire control personnel could be prepared to modify control tactics as might be required.

CONCLUSIONS

1. Two wildfires that occurred in coastal North Carolina in April 1966 were characterized by numerous shifts in wind direction; these shifts presented severe control problems and resulted in the burning of sizable acreages.

2. Unusual behavior of the Air Force Range Fire was due to several shifts in wind direction caused by the oscillatory passage of a sea breeze front. Low humidities on both sides of the sea breeze front also contributed to the fire's behavior.

3. Unusual behavior of the Holly Shelter Fire was due to wind shifts resulting from passages of a pressure trough line, a sea breeze front, and a surface cold front.

4. In the Holly Shelter Fire, the surface cold front advanced over the fire site, stopped briefly, and then retreated. This behavior of the front is believed to have resulted from heat released by the fire.

5. Although timely and detailed analyses may be required to evaluate synoptic weather features important to fire behavior, forecasts and warnings of their effects are possible. Furthermore, knowledge of the potential influence of these weather features on fire behavior can be used by fire control personnel in planning control tactics.

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Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part II--Sand Pine
(*Pinus clausa* (Chapm.) Vasey)

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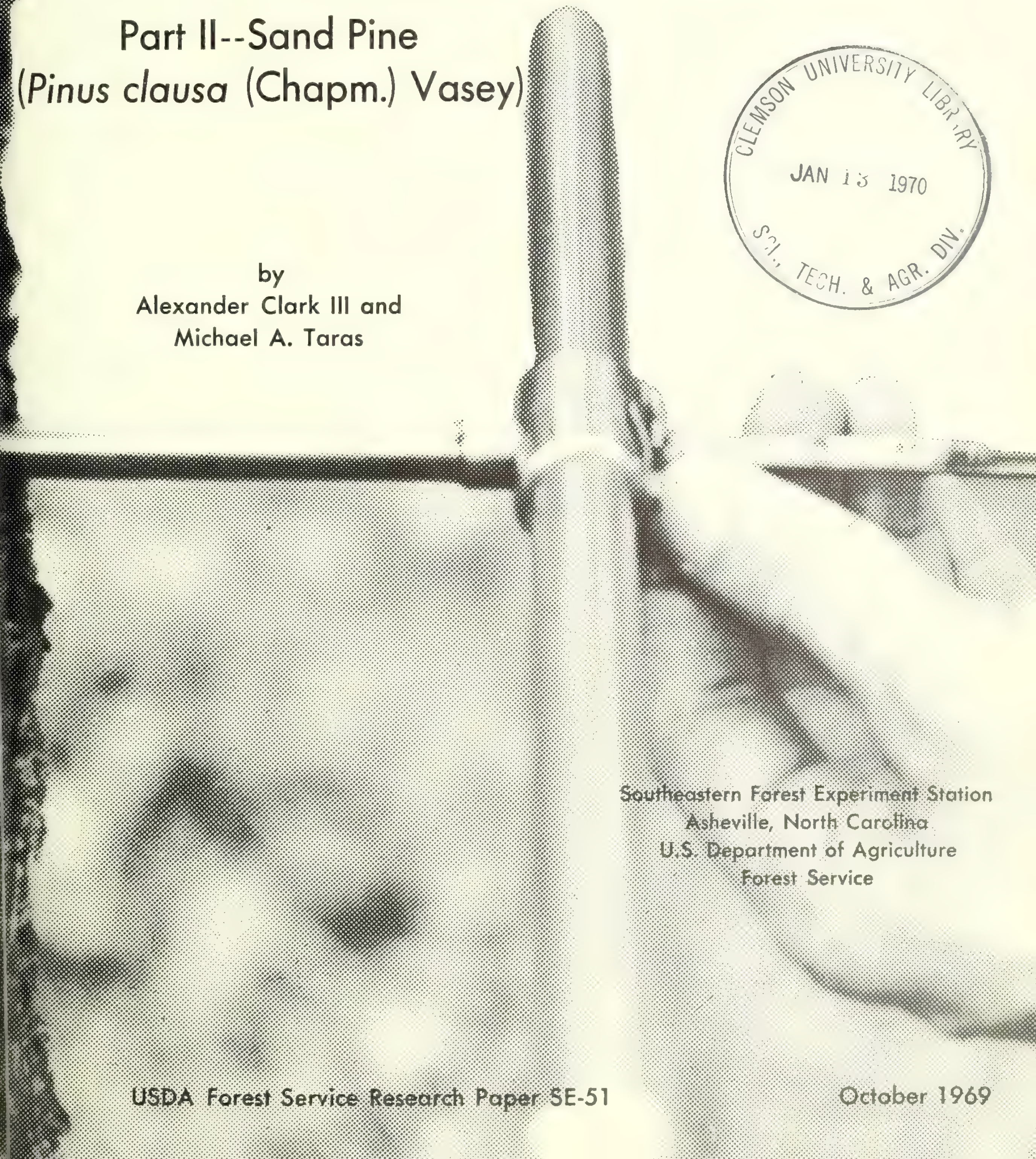

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U.S. Department of Agriculture
Forest Service

USDA Forest Service Research Paper SE-51

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Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part II--Sand Pine (Pinus clausa (Chapm.) Vasey)

by

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and
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INTRODUCTION

This report is the second of a series covering wood density surveys of the minor species of yellow pine in the Eastern United States.[1] Literature review and historical information regarding these surveys were presented in "Part I—Spruce Pine (*Pinus glabra* Walt.)" by Taras and Saucier (1968) and will not be repeated here.

The objectives of the survey were:

(1) To obtain data that will provide an estimate of the average specific gravity of unextracted and extracted wood of each minor species, and establish the degree of variation about each mean.

(2) To evaluate increment core/tree specific gravity relationships and develop regression equations for predicting tree specific gravity from increment core specific gravity.

(3) To examine the geographic trends of wood specific gravity within the range of each species, from east to west and from north to south.

MATERIALS AND METHODS

Species

Sand pine (*Pinus clausa* (Chapm.) Vasey), also called scrub pine or spruce pine, is the only species discussed in this report. Harlow and Harrar (1950) describe sand pine as a small tree, of poor form (fig. 1A), commonly found on slightly acid, sterile sandy soils in Florida and characterized by narrowly ovoid-conic cones which are often persistent for many years or until opened by the heat of a forest fire. The scientific name *clausa*, meaning closed, refers to this feature. The needles are about 3 inches long, slender, flexible, and in fascicles of two (fig. 1B). The bark is comparatively smooth, becoming plated only on the lower trunks and large branches (fig. 1C). In the crown part of the trunk the bark is orange-brown and appears to blister and have curly flakes (fig. 1D). Except for a small area in southeastern Alabama, the range of this species is confined to Florida (fig. 2).

Two races of this species have been named by Little and Dorman (1952). They proposed the name "Ocala sand pine" for the race with closed cones growing in eastern Florida and "Choctawhatchee sand pine" for the race having open or normal cones and growing in western Florida. Ocala sand pine forms even-aged, single species forests of narrow, pointed trees, 20 to 50 feet high. It grows most extensively on the Ocala National Forest in

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[1] This study was conducted in cooperation with the Forest Products Laboratory, the Northeastern Forest Experiment Station, the Southern Forest Experiment Station, and state forestry services, the pulp and paper industries, the southern pine plywood and sawmill industry, and numerous private forest owners throughout the Southern and Eastern United States.

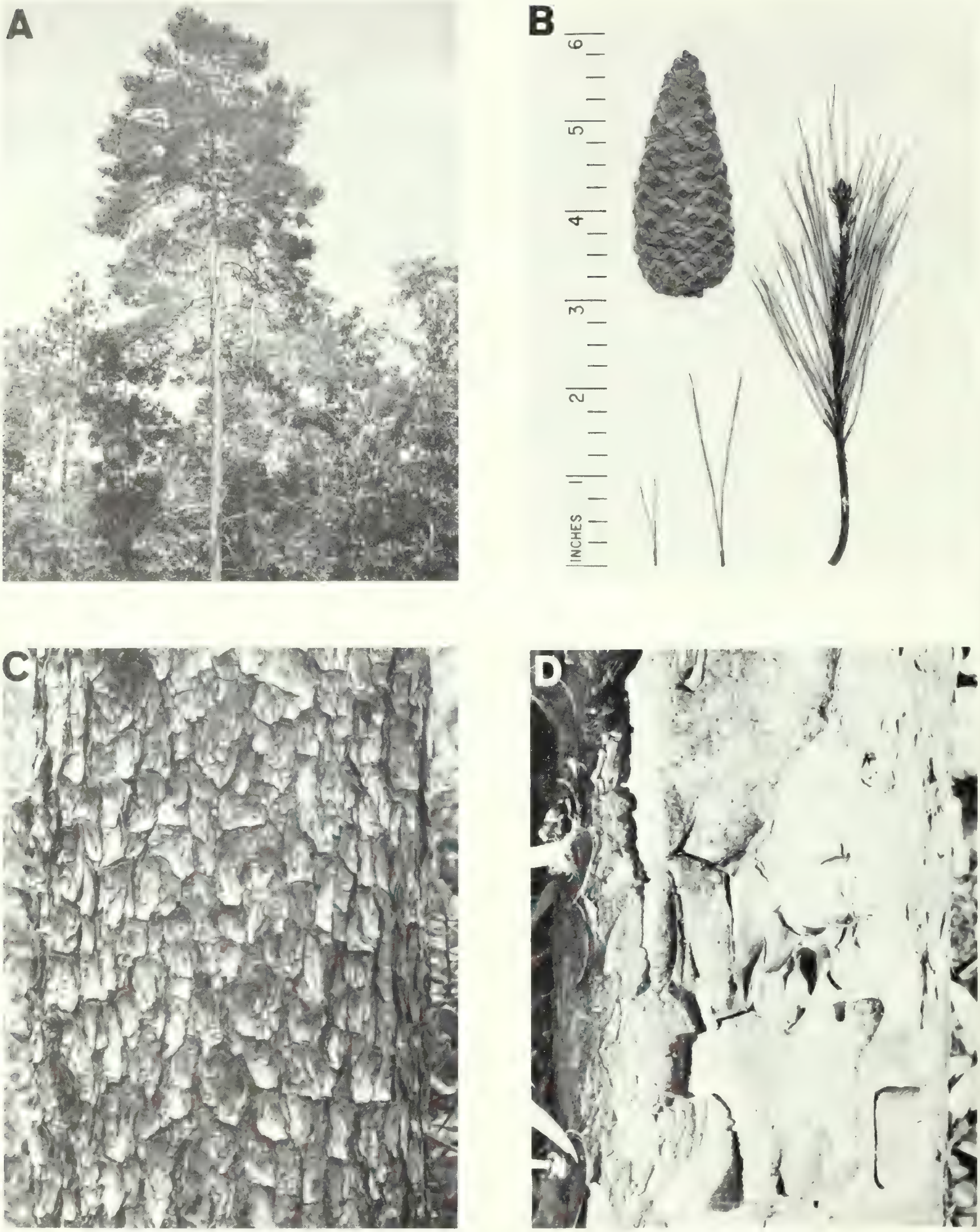

Figure 1.—*Botanical features of sand pine: (A) tree form; (B) branchlet, cones, and needles; (C) bark of mature tree; (D) young bark on upper bole and branches of a mature tree.*

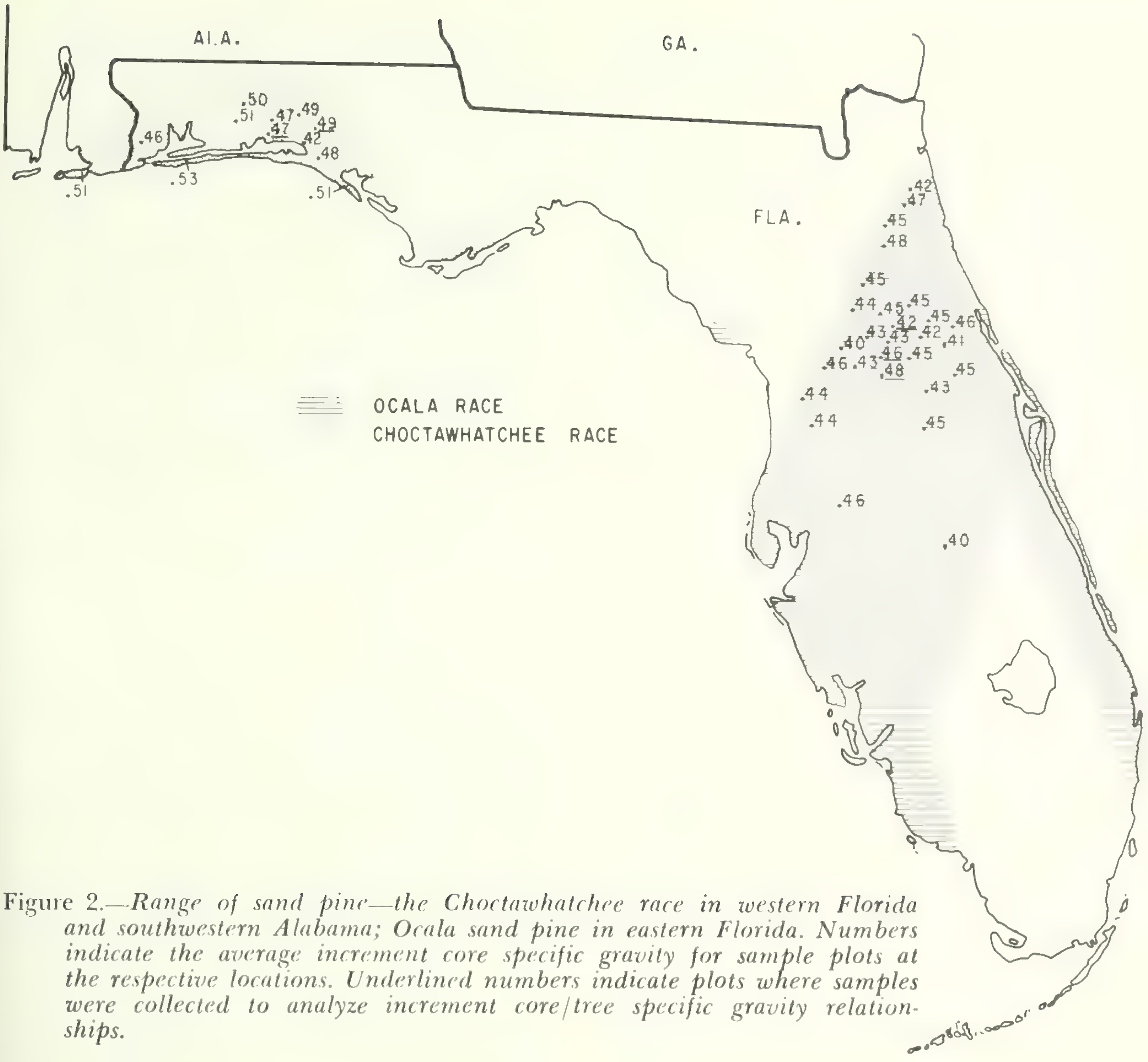

Figure 2.—*Range of sand pine—the Choctawhatchee race in western Florida and southwestern Alabama; Ocala sand pine in eastern Florida. Numbers indicate the average increment core specific gravity for sample plots at the respective locations. Underlined numbers indicate plots where samples were collected to analyze increment core/tree specific gravity relationships.*

north-central Florida, where it covers about 280,000 acres. The Choctawhatchee sand pine forests, on the other hand, consist of uneven-aged stands mixed with small amounts of scrub oaks, including live oak (*Quercus virginiana* var. *geminata* (Small) Sarg.), turkey oak (*Q. laevis* Walt.), and myrtle oak (*Q. myrtifolia* Willd.).

Forest Survey Release No. 57 by Larson and Goforth (1961) lists the total predicted commercial forest land supporting sand pine in Florida as 422,000 acres. Ocala sand pine occurs on 374,000 acres while Choctawhatchee sand pine is found on only 48,000 acres. The total standing volume of timber indicated by Forest Survey is approximately 90 million cubic feet of wood—about 80 million cubic feet of Ocala and 10 million cubic feet of Choctawhatchee.

Field Sampling Procedure

To meet the objectives of the study, 35 plots were sampled throughout the range of the species. Ocala sand pine was sampled at 25 locations throughout its range and Choctawhatchee was sampled at 10 locations. We calculated the number of trees per plot had to be 20, in order to obtain an estimate of the mean wood density with a 95 percent confidence interval width of .02. With the 3.03 diopter prism, a sufficient number of sampling points were selected (using random azimuths and distances between points) so at least 20 trees could be sampled at each plot location. The total number of trees sampled was 716. The plots were selected randomly, with replacement, with the probability roughly proportional to the volume of the species within Forest Survey Units[2] containing sand pine. A 6-mile grid system was used to locate plots randomly within survey units.

Two increment cores were removed from opposite sides of each sample tree. Cores were stored in a 4-percent solution of formaldehyde immediately after being removed from the tree and were shipped green to the laboratory. The total height, merchantable height to a 4-inch top, and d.b.h. of each sample tree were sampled.

The trees to be used for analyzing increment core/tree specific gravity relationships were randomly selected at two locations within the range of the Choctawhatchee race and at three locations within the range of the Ocala race (fig. 2). Two increment cores were taken from each of 25 to 34 trees at each location before they were felled. Beginning at the butt end of the tree, 1-inch-thick disks were cut at 5-foot intervals to a 4-inch top. Total height and merchantable height to a 4-inch top of each tree were recorded, as was the diameter of each disk.

Laboratory Procedures

The specific gravity of all increment cores was determined in the unextracted and extracted condition by the maximum moisture method described by Smith (1954). All cores were subjected to a vacuum treatment for several days to insure complete water saturation. Wood disks were soaked for several days and their specific gravities determined by the buoyancy method described by Heinrichs (1954). The results are based on green volume and ovendry weight.

Increment cores from all trees were extracted after unextracted specific gravity was determined. Extractions were made with a mixture of two parts benzene and one part ethyl alcohol for 24 hours. Following extraction, the cores were saturated with water, and their specific gravity determined by the maximum moisture method. No wood disks were extracted.

From the sample of trees collected to analyze increment core/tree specific gravity relationships, each increment core was divided into three equal parts and specific gravity determined for each segment. The purpose was to obtain a weighted increment core specific gravity, and to examine the relationship of parts (1/3 and 2/3 only) of increment cores to total tree specific gravity. Weighted total core specific gravity was determined by weighting the specific gravities of segments by the cross-sectional areas the segments represented.

Average specific gravity of the individual 5-foot bolts within each tree was computed as the mean of the bolt's terminal disks. The average specific gravity of the tree was determined by weighting the average bolt specific gravity by bolt volume. Formulas for all these computations are shown in the Appendix. A discussion of the analysis of the increment core/tree specific gravity relationship data is presented in an office report available from the Forestry Sciences Laboratory, Carlton Street, Athens, Georgia 30601.

RESULTS AND DISCUSSION

Sand Pine Specific Gravity and Its Variation

The average specific gravity of *unextracted* Ocala sand pine increment cores was .439, based on the average of two whole increment cores from each of 523 sample trees collected over the entire range of the race. The standard error of the mean increment core specific gravity was .004, and the standard deviation about the mean of the individual observations was .037. Choctawhatchee sand pine had an average unextracted increment core specific gravity of .485, based on two whole cores from each of 193 sample trees. The standard error was .003, and standard deviation of individual observations was .045.

The average specific gravity of *extracted* increment cores from Ocala sand pine was .407; standard error was .004 and standard deviation of individuals was .030. Extracted increment cores of Choctawhatchee sand pine had an average specific gravity of .442, with a standard error of .003 and a standard deviation of .032 for individual observations. Specific gravity of unextracted Ocala sand pine increment cores was 7.86 percent higher than the extracted increment core specific gravity; the unextracted specific gravity of Choctawhatchee sand pine increment cores was 9.73 percent higher than the extracted specific gravity. Both races of sand pine contain a large amount of extractives, compared to the four major southern yellow pines which normally contain 6.0 to 7.5 percent extractives (Taras and Saucier 1967).

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[2] Forest Survey Units are subdivisions of a state based in part on county boundaries and in part on the physiography of the state. They are established for the purpose of sampling and reporting results efficiently.

Extracting Choctawhatchee increment cores reduced the standard deviation of individuals about the mean from .045 to .032, which compares favorably with the standard deviation of extracted Ocala increment cores (.030). The average specific gravity of unextracted and extracted increment cores for both races is shown in table 1.

Analysis of variance showed that specific gravities of unextracted and extracted increment cores from Choctawhatchee sand pine were significantly higher than those of Ocala sand pine at the .001 probability level (table 2). The difference in average specific gravity of unextracted increment cores between the two races lies within the confidence interval: $P[.034 < \mu < .058] = .999$. One reason for this difference in increment core specific gravity might be that Choctawhatchee trees averaged 9 years older than the Ocala trees, and thus contained a smaller proportion of juvenile wood of low specific gravity. This difference in age could be important because the Ocala trees sampled averaged only 25 years (table 1).

The average unextracted tree specific gravity for Ocala sand pine was computed with the following regression equation:

Table 1.—*Specific gravity of unextracted and extracted increment cores from Ocala and Choctawhatchee sand pine*

OCALA SAND PINE

Plot number	County and state	Trees in sample	Mean d.b.h.	Mean age	Unextracted		Extracted		Difference between means
					Mean and standard error	Standard deviation	Mean and standard error	Standard deviation	
		Number	*Inches*	*Years*					*Percent*
1	St. Johns, Fla.	21	7.4	28	.465 (.006)	.028	.433 (.007)	.030	7.39
2	Clay, Fla.	20	9.1	24	.479 (.012)	.052	.429 (.008)	.034	11.65
3	Putnam, Fla.	21	10.3	30	.451 (.008)	.036	.423 (.008)	.034	6.62
4	St. Johns, Fla.	21	7.7	20	.416 (.006)	.026	.395 (.005)	.024	5.32
5	Marion, Fla.	22	7.6	36	.450 (.007)	.032	.424 (.006)	.030	6.13
6	Marion, Fla.	21	8.9	34	.443 (.006)	.029	.418 (.006)	.028	5.98
7	Marion, Fla.	26	8.9	30	.434 (.007)	.037	.408 (.006)	.031	6.37
8	Volusia, Fla.	24	8.3	22	.419 (.007)	.034	.397 (.007)	.033	5.54
9	Volusia, Fla.	20	8.5	24	.448 (.009)	.040	.414 (.008)	.034	8.21
10	Volusia, Fla.	20	10.6	31	.459 (.010)	.044	.419 (.008)	.037	9.55
11	Volusia, Fla.	20	8.4	18	.412 (.007)	.032	.391 (.007)	.029	5.37
12	Marion, Fla.	20	8.6	34	.446 (.008)	.036	.415 (.007)	.029	7.47
13	Marion, Fla.	21	7.8	42	.454 (.007)	.034	.429 (.007)	.034	5.83
14	Marion, Fla.	20	6.7	16	.400 (.009)	.038	.369 (.004)	.019	8.40
15	Marion, Fla.	23	5.7	28	.430 (.007)	.032	.404 (.006)	.028	6.70
16	Marion, Fla.	20	8.9	28	.451 (.008)	.037	.423 (.008)	.037	6.62
17	Citrus, Fla.	22	8.0	25	.442 (.008)	.036	.412 (.005)	.025	7.28
18	Marion, Fla.	20	10.8	20	.416 (.009)	.042	.382 (.007)	.032	8.90
19	Marion, Fla.	20	10.0	29	.435 (.009)	.042	.406 (.008)	.038	7.14
20	Seminole, Fla.	20	12.3	18	.434 (.010)	.044	.393 (.007)	.029	10.43
21	Volusia, Fla.	20	8.0	20	.445 (.007)	.032	.408 (.008)	.036	9.07
22	Lake, Fla.	20	9.6	18	.453 (.010)	.044	.413 (.011)	.049	9.69
23	Hernando, Fla.	20	10.5	22	.441 (.008)	.036	.401 (.007)	.030	9.98
24	Hillsboro, Fla.	20	10.6	21	.459 (.010)	.046	.412 (.008)	.037	11.41
25	Polk, Fla.	21	6.2	14	.402 (.008)	.035	.368 (.005)	.024	9.24
	Total	523	8.8	25	.439 (.004)	.037	.407 (.004)	.030	7.86
	CHOCTAWHATCHEE SAND PINE								
1	Franklin, Fla.	33	7.1	29	.505 (.006)	.035	.462 (.005)	.030	9.31
2	Walton, Fla.	21	9.3	29	.479 (.007)	.032	.449 (.006)	.027	6.68
3	Walton, Fla.	24	6.9	17	.416 (.003)	.017	.395 (.004)	.018	5.32
4	Walton, Fla.	21	11.4	31	.469 (.005)	.024	.424 (.004)	.020	10.61
5	Walton, Fla.	21	10.8	34	.496 (.010)	.047	.439 (.009)	.041	12.98
6	Walton, Fla.	19	9.5	32	.491 (.006)	.026	.435 (.004)	.017	12.87
7	Okaloosa, Fla.	20	12.2	48	.506 (.007)	.030	.466 (.006)	.027	8.58
8	Santa Rosa, Fla.	8	9.3	37	.528 (.020)	.057	.459 (.008)	.023	15.03
9	Escambia, Fla.	6	10.6	37	.463 (.013)	.031	.435 (.009)	.021	6.44
10	Baldwin, Ala.	20	9.6	44	.509 (.013)	.057	.460 (.008)	.036	10.65
	Total	193	9.7	34	.485 (.003)	.045	.442 (.003)	.032	9.73

$$\text{Tree specific gravity } (Y) = 0.26222 + 0.56947 \text{ (sp. gr., 2 extracted cores)} - 0.19747 \text{ (d.b.h./age)} \quad (1)$$

When the specific gravity of the 523 Ocala sand pine trees sampled by increment cores was adjusted to whole tree specific gravity by using equation (1), the average unextracted tree specific gravity was .419, with a standard error of .003.

Table 2.—*Analyses of variance of increment core specific gravity for Ocala sand pine and Choctawhatchee sand pine*

Source	d.f.	Unextracted		Extracted	
		MS	F ratio	MS	F ratio
Between races	1	0.2972	174.82***	0.1720	143.33***
Within races	714	0.0017		0.0012	
Total	715				

***Significant at the .001 probability level.

The average unextracted tree specific gravity for Choctawhatchee sand pine trees was computed with the following regression equation:

$$\text{Tree specific gravity } (Y) = 0.14879 + 0.78915 \text{ (sp. gr., 2 extracted cores)} - 0.05552 \text{ (d.b.h./age)} \quad (2)$$

When the increment core specific gravity of the 193 Choctawhatchee trees sampled was adjusted by using equation (2), the average unextracted tree specific gravity was .482, with a standard error of .008.

The specific gravities of unextracted increment cores by diameter classes (5.0 to 8.9 inches; 9.0 to 14.9 inches; and 15.0+ inches) are shown in table 3 for each Forest

Table 3.—*Specific gravity data for Ocala and Choctawhatchee sand pine by states and by Forest Survey Units within states*

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Unextracted increment core specific gravity		Estimated tree specific gravity[1] mean and standard error	Approx. timber volume[2]
				Mean and standard error	Standard deviation		
	Number	*Inches*	*Number*				*Million cu. ft.*
OCALA SAND PINE							
Florida							
Northeast (1)	19	5.0-8.9	254	.438 (.005)	.034	.437 (.003)	42.4
		9.0-14.9	136	.441 (.006)	.043	.418 (.005)	18.0
		15.0+	10	.449 (.018)	.065	.379 (.017)	0.9
Central (3)	6	5.0-8.9	68	.425 (.008)	.048	.397 (.008)	13.0
		9.0-14.9	44	.452 (.008)	.041	.385 (.010)	5.1
		15.0+	11	.465 (.003)	.054	([3])	0.1
State total	25	5.0-8.9	322	.435 (.004)	.035	.433 (.003)	55.4
		9.0-14.9	180	.444 (.005)	.041	.403 (.006)	23.1
		15.0+	21	.458 (.003)	.056	([3])	1.0
Total all classes	25		523	.439 (.004)	.037	.419 (.004)	79.5
CHOCTAWHATCHEE SAND PINE							
Alabama							
Southwest (1)	1	5.0-8.9	9	.501 (.019)	.057	.497 (.012)	—
		9.0-14.9	11	.515 (.017)	.056	.502 (.011)	—
		15.0+	0	0	0	0	—
Florida							
Northwest (2)	9	5.0-8.9	90	.480 (.020)	.053	.480 (.004)	8.8
		9.0-14.9	72	.484 (.006)	.037	.478 (.005)	1.1
		15.0+	11	.489 (.009)	.057	.472 (.012)	—
Total both states	10	5.0-8.9	99	.482 (.018)	.053	.482 (.004)	8.8
		9.0-14.9	83	.488 (.005)	.056	.481 (.005)	1.1
		15.0+	11	.489 (.009)	.057	.472 (.012)	—
Total all classes	10		193	.485 (.003)	.045	.482 (.003)	9.9

[1] Estimates were made using equation (1) for Ocala and equation (2) for Choctawhatchee sand pine.

[2] From Forest Survey data of the Southern and Southeastern Forest Experiment Stations.

[3] The mean d.b.h./age ratio for the 15.0+ inch diameter class lies outside the range for which equation (1) can be used with confidence to estimate tree specific gravity.

Survey Unit sampled. In table 3 the estimated tree specific gravity and standard error for Ocala sand pine have been omitted for the 15.0+ inches diameter class for both the Central Survey Unit and the state total. This deletion was necessary because the average tree sampled only by increment cores represents a population growing much faster than the 84 trees used to develop the regression equation for Ocala sand pine. The 15.0+ class trees in the Central Survey Unit had an average d.b.h./age ratio of .779, and ranged from .410 to 1.069; the trees used to develop the regression equation had an average d.b.h./age ratio of .240 with a standard deviation of 0.121, and ranged from .110 to .600 (table 4). Since the mean d.b.h./age ratio for the 15.0+ class falls outside the range of the d.b.h./age data used to develop the regression equation, little confidence can be placed in estimates of tree specific gravity in that class. Equation (1) should not be used for estimating tree specific gravity for trees growing faster than .6 inch per year.

The estimated tree specific gravity data shown in table 3 are reproduced in figure 3 to illustrate the distribution of diameter classes and their specific gravities within each Forest Survey Unit.

Geographic Variation

The data in table 1 are also shown in figure 2 to illustrate specific gravity changes with geographic location. In figure 2 there appear to be no geographic trends from north to south or east to west except for the previously noted difference between races—Choctawhatchee growing in western Florida and Ocala in eastern Florida. There appears to be little change in specific gravity over the entire range of each race, compared to some of the major yellow pines. This relative uniformity in specific gravity may result because sand pine grows on restricted sites and not over a wide variety of sites and moisture conditions. The differences in specific gravity which occur between plots (figure 2) were not extremely large (maximum difference between plots for Ocala sand pine was .08 and for Choctawhatchee was .11), but were statistically significant at the .001 probability level. Analyses of variance showing mean squares and F ratio are presented in table 5.

Table 4.—*Mean and standard deviation of the dependent and independent variables used to develop regression equations for the increment core/tree specific gravity relationships for Choctawhatchee and Ocala sand pine*

	Choctawhatchee		Ocala	
Variables	Mean	Standard deviation	Mean	Standard deviation
Dependent				
Weighted tree specific gravity	0.475	0.029	0.451	0.042
Independent				
D.b.h.	10.776	3.711	8.720	2.776
Total height	54.370	7.783	51.262	10.414
Age	44.074	9.572	41.988	13.825
Merchantable volume	16.667	11.551	11.131	9.795
D.b.h./age	0.246	0.072	0.240	0.121
1/age	0.024	0.005	0.029	0.016
Merchantable volume/age	0.365	0.219	0.268	0.198
Total height/age	1.277	0.279	1.363	0.484
Specific gravity, 1 core	0.475	0.036	0.448	0.037
Specific gravity, outer 2/3 of 1 core	0.488	0.040	0.467	0.042
Specific gravity, outer 1/3 of 1 core	0.492	0.051	0.467	0.049
Specific gravity, 2 cores	0.481	0.033	0.450	0.038
Specific gravity, outer 2/3 of 2 cores	0.493	0.032	0.472	0.044
Specific gravity, outer 1/3 of 2 cores	0.496	0.041	0.476	0.048
Weighted specific gravity, 1 core	0.485	0.039	0.461	0.040
Weighted specific gravity, 2 cores	0.490	0.033	0.466	0.042
Specific gravity, 1 extracted core	0.425	0.027	0.413	0.033
Specific gravity, outer 2/3 of 1 extracted core	0.447	0.032	0.434	0.036
Specific gravity, outer 1/3 of 1 extracted core	0.453	0.046	0.435	0.041
Specific gravity, 2 extracted cores	0.430	0.026	0.414	0.031
Specific gravity, outer 2/3 of 2 extracted cores	0.451	0.030	0.437	0.034
Specific gravity, outer 1/3 of 2 extracted cores	0.461	0.039	0.441	0.038
Weighted specific gravity, 1 extracted core	0.441	0.032	0.427	0.034
Weighted specific gravity, 2 extracted cores	0.446	0.029	0.430	0.033

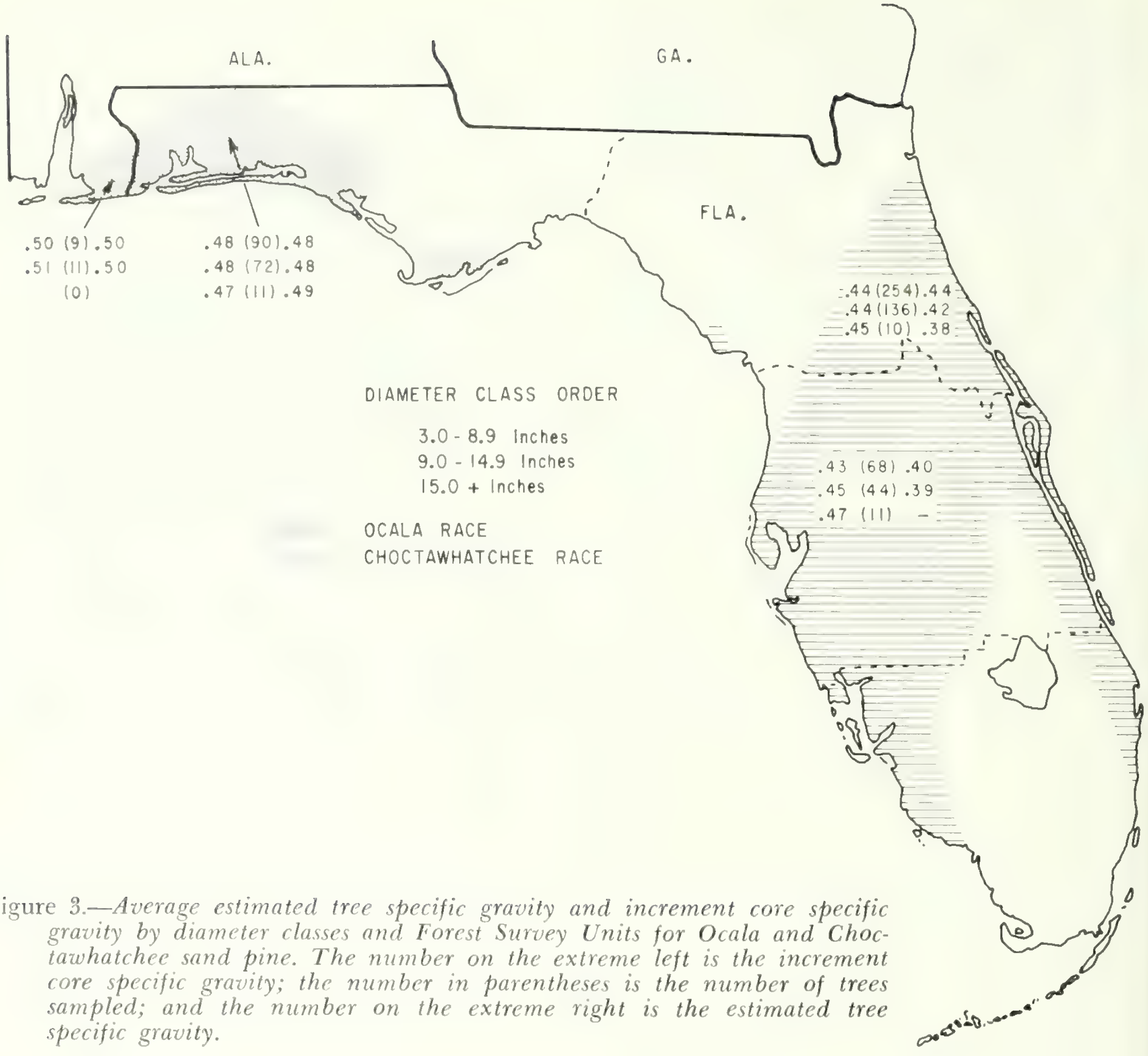

Figure 3.—*Average estimated tree specific gravity and increment core specific gravity by diameter classes and Forest Survey Units for Ocala and Choctawhatchee sand pine. The number on the extreme left is the increment core specific gravity; the number in parentheses is the number of trees sampled; and the number on the extreme right is the estimated tree specific gravity.*

Table 5.—*Analyses of variance for Ocala and Choctawhatchee sand pine specific gravity and test of significance for locations*

Source	d.f.	Unextracted		Extracted	
		MS	F ratio	MS	F ratio
CHOCTAWHATCHEE SAND PINE					
Among locations	9	0.0160	12.3070***	0.0091	11.3750***
Within locations	183	0.0013		0.0008	
Total	192				
OCALA SAND PINE					
Among locations	24	0.0080	6.1538***	0.0062	6.2000***
Within locations	498	0.0013		0.0010	
Total	522				

***Significant at the .001 probability level.

(2) with 56 percent of the variation in tree specific gravity. These associations are only 7 percent and 2 percent less than the best equations developed.

Relationship of Unextracted to Extracted Specific Gravity

The specific gravity of all increment cores was determined in both the unextracted and extracted condition. A linear regression was used to analyze these data for each race. The results show that in both races the same high correlation ($r = .88$) exists for the specific gravity relationship between unextracted and extracted increment cores. In the following equations, the unextracted increment core specific gravity is associated with 77 percent of the total variation in extracted increment core specific gravity:

$$Y = 0.11681 + 0.67118\,X_1 \qquad \overset{*}{(3)}$$

Where Y = extracted increment core specific gravity of Ocala sand pine

X_1 = unextracted increment core specific gravity of Ocala sand pine

pine to .407, a difference of 7.86 percent. Extraction reduced the specific gravity of increment cores from Choctawhatchee sand pine from .485 to .442, a difference of 9.73 percent. This indicates Choctawhatchee sand pine contains more extractives than any other eastern yellow pine examined in this laboratory.

Equations are presented for predicting specific gravity of extracted increment cores from the specific gravity of unextracted increment cores from both races. In both equations, the specific gravity of unextracted increment cores is associated with 77 percent of the total variation in specific gravity of extracted increment cores.

The specific gravities of unextracted and extracted increment cores of Choctawhatchee sand pine were significantly higher than those of Ocala sand pine. The difference in average specific gravity of unextracted increment cores between the two races lies within the confidence interval: $P[.034 < \mu < .058] = .999$. There appear to be no distinct north-south or east-west geographic trends in specific gravity within the range of either race.

* see insert

The best equation developed for Ocala sand pine involved three independent variables: (1) weighted specific gravity of two extracted cores, (2) d.b.h./age, and (3) d.b.h. These variables were associated with 79 percent of the total variation in tree specific gravity. The best equation for Choctawhatchee sand pine involved: (1) weighted specific gravity of two unextracted cores, (2) total height, and (3) d.b.h./age. These variables were associated with 58 percent of the total variation in tree specific gravity. The following equations were used to adjust increment core specific gravity values to tree specific gravity because the increment cores taken in the survey were not segmented when their specific gravities were determined:

$$Y = 0.26222 + 0.56947 \text{ (sp. gr., 2 extracted cores)} - 0.19747 \text{ (d.b.h./age)} \quad (1)$$

$$Y = 0.14879 + 0.78915 \text{ (sp. gr., 2 extracted cores)} - 0.05552 \text{ (d.b.h./age)} \quad (2)$$

Equation (1) was used to adjust Ocala sand pine increment core specific gravity to tree specific gravity and explained 72 percent of the variation. Equation (2) was used to adjust Choctawhatchee sand pine increment core specific gravity to tree specific gravity and explained 56 percent of the variation.

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APPENDIX

Computational Procedures

1. Increment core specific gravity $= \frac{\text{ovendry weight of core}}{\text{green weight of core} - .3464\,(\text{ovendry weight of core})}$

2. Disk specific gravity $= \frac{\text{ovendry weight of disk}}{\text{displaced volume of disk}}$

3. Bolt specific gravity $= \frac{\text{specific gravity top disk} + \text{specific gravity bottom disk}}{2}$

4. Tree specific gravity $= \frac{\sum_{1-n} (\text{bolt volume} \times \text{bolt specific gravity})}{\sum_{1-n} \text{bolt volumes}}$

5. Bolt volume = bolt length, feet $\times \left[\frac{.005454(\text{d.i.b.})_t^2 + .005454(\text{d.i.b.})_b^2}{2} \right]$

   where: t = top of bolt
   b = base of bolt

6. (a) Mean core specific gravity $x = \frac{\sum_i \sum_j X_{ij}}{m_1 n_1}$

   where: X_{ij} = the core specific gravity for the jth tree at the ith location
   m_1 = number of trees at each location
   n_1 = number of locations

   (b) The standard deviation of individuals was estimated from the sample range of the core specific gravities using the tabular values of the ratio of the standard deviation to the range.

7. Tree specific gravities were estimated from regression by:

   (a) Tree specific gravity $(Y) = b_0 + b_1X_1 + b_2X_2$

   where: Y = tree specific gravity
   X_1 = average specific gravity of 2 extracted cores
   X_2 = d.b.h./age

   (b) The standard error of the predicted mean tree specific gravity was estimated by--

$$S_{\hat{y}} = \left[S^2_{y\cdot x}\left(\frac{1}{m_2 n_2} + C_{11}(\bar{x}_{1.1} - \bar{x}_{1.2})^2 + C_{22}(\bar{x}_{2.1} - \bar{x}_{2.2})^2 + 2C_{12}(\bar{x}_{1.1} - \bar{x}_{1.2})(\bar{x}_{2.1} - \bar{x}_{2.2}) \right) + \frac{S^2_y}{m_1 n_1} \right]^{\frac{1}{2}}$$

   where: $S^2_{y.x}$ = residual mean squares
   S^2_y = variance of y prior to adjustment for regression
   $\bar{x}_{1.1}$ = mean core specific gravity of trees from which only cores were collected, sample (1)
   $\bar{x}_{1.2}$ = mean core specific gravity of trees collected for tree-core relationships, sample (2)
   $\bar{x}_{2.1}$ = mean d.b.h./age for sample (1)
   $\bar{x}_{2.2}$ = mean d.b.h./age for sample (2)
   m_1 = number of trees at each location, sample (1)
   m_2 = number of trees at each location, sample (2)
   n_1 = number of locations, sample (1)
   n_2 = number of locations, sample (2)

(c) The standard error of the core mean was approximated by the following computation when the variances were pooled to obtain the mean core specific gravity of more than one location:

$$\text{standard error} = \sqrt{\frac{K}{(\Sigma n_i)^2}\left(\frac{\Sigma S_i^2 + \bar{x}^2 \Sigma n_i^2 - 2\bar{x}\Sigma n_i S_i}{K-1}\right)}$$

where: K = the number of locations at which trees were bored for specific gravity

S_i = the sum of specific gravities of cores at the ith location ($= \Sigma_j X_{ij}$)

(d) When variances were not pooled the standard error of the mean was approximated by--

$$\text{standard error} \quad \frac{S}{\sqrt{n}}$$

where: S = standard deviation estimated from the sample range of core specific gravities

n = number of observations in sample

8. Percentage difference in specific gravity due to extraction $= \dfrac{\text{unextracted core sp. gr. - extracted core sp. gr.}}{\text{extracted core sp. gr.}} \times 100$

Table 6.—*Regression equations, correlation coefficients, coefficients of determination, and standard errors for Ocala sand pine increment core/tree specific gravity relationships*

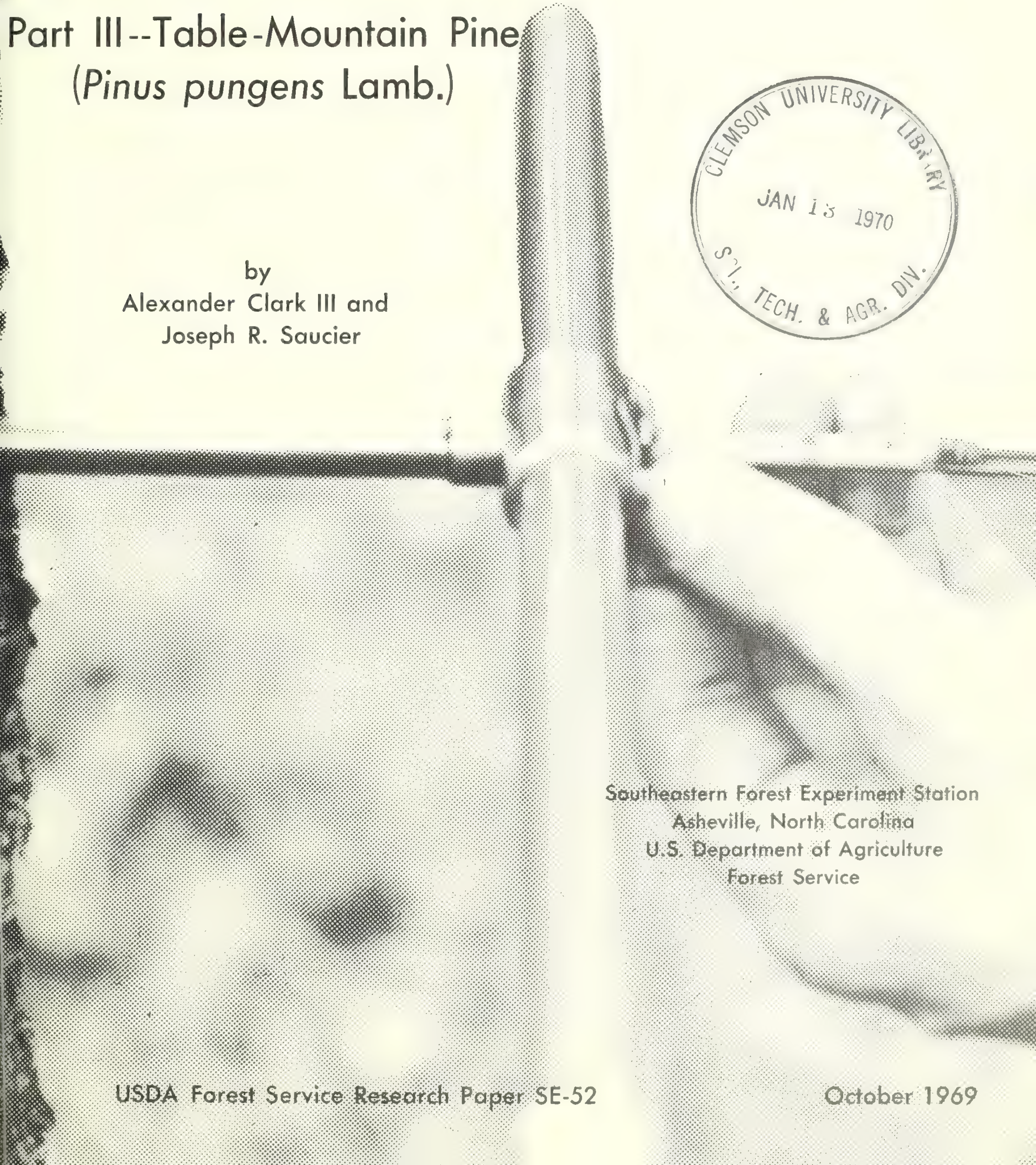
Regression equations	r	r^2	Standard error
Tree specific gravity (Y):			
Y = 0.23819 + 0.63621 (weighted sp. gr., 2 extracted cores) — 0.15399 (d.b.h./age) — 0.00277 (d.b.h.)	0.89	0.79	0.020
Y = 0.16814 + 0.58458 (weighted sp. gr., 2 cores) — 0.06927 (merch. vol./age) + 0.00069 (age)	0.89	0.79	0.019
Y = 0.23253 + 0.63061 (sp. gr., outer 2/3 of 2 extracted cores) — 0.14792 (d.b.h./age) — 0.000250 (d.b.h.)	0.89	0.79	0.020
Y = 0.17710 + 0.55341 (sp. gr., outer 2/3 of 2 cores) — 0.06488 (merch. vol./age) + 0.00071 (age)	0.89	0.79	0.019
Y = 0.11672 + 0.75105 (weighted sp. gr., 2 cores) — 0.05899 (merch. vol./age)	0.88	0.77	0.020
Y = 0.20802 + 0.64408 (sp. gr., outer 2/3 of 2 extracted cores) — 0.16113 (d.b.h./age)	0.88	0.77	0.021
Y = 0.12667 + 0.71611 (sp. gr., outer 2/3 of 2 cores) — 0.05299 (merch. vol./age)	0.88	0.77	0.021
Y = 0.19236 + 0.54993 (sp. gr., 2 cores) — 0.09074 (merch. vol./age) + 0.00084 (age)	0.88	0.77	0.020
Y = 0.26691 + 0.62005 (sp. gr., 2 extracted cores) — 0.16832 (d.b.h./age) — 0.00374 ((d.b.h.)	0.88	0.77	0.021
Y = 0.24863 + 0.49905 (sp. gr., outer 1/3 of 2 cores) — 0.12002 (d.b.h./age) — 0.00058 (merch. vol.)	0.88	0.77	0.021
Y = 0.21608 + 0.64057 (weighted sp. gr., 2 extracted cores) — 0.17043 (d.b.h./age)	0.87	0.76	0.021
Y = 0.23304 + 0.51868 (sp. gr., outer 1/3 of 2 cores) — 0.12107 (d.b.h./age)	0.87	0.76	0.021
Y = 0.29657 + 0.50958 (sp. gr., 1 core) — 0.16497 (d.b.h./age) — 0.00394 (d.b.h.)	0.87	0.76	0.021
Y = 0.28981 + 0.47028 (sp. gr., outer 2/3 of 1 core) — 0.15049 (d.b.h./age) — 0.00261 (d.b.h.)	0.87	0.76	0.021
Y = 0.27504 + 0.51068 (weighted sp. gr., 1 core) — 0.14584 (d.b.h./age) — 0.00281 (d.b.h.)	0.87	0.76	0.021
Y = 0.13273 + 0.75684 (sp. gr., 2 cores) — 0.08518 (merch. vol./age)	0.86	0.74	0.022
Y = 0.31676 + 0.48044 (weighted sp. gr., 1 extracted core) — 0.18768 (d.b.h./age) — 0.00300 (d.b.h.)	0.86	0.74	0.022
Y = 0.32674 + 0.49577 (sp. gr., 1 extracted core) — 0.19335 (d.b.h./age) — 0.00395 (d.b.h.)	0.86	0.74	0.022
Y = 0.30818 + 0.46094 (sp. gr., outer 1/3 of 2 extracted cores) — 0.17661 (d.b.h./age) — 0.00209 (d.b.h.)	0.86	0.74	0.022
Y = 0.31697 + 0.46886 (sp. gr., outer 2/3 of 1 extracted core) — 0.18738 (d.b.h./age) — 0.00281 (d.b.h.)	0.86	0.74	0.022
Y = 0.06855 + 0.80901 (sp. gr., outer 2/3 of 2 cores)	0.85	0.72	0.023
Y = 0.26222 + 0.56947 (sp. gr., 2 extracted cores) — 0.19747 (d.b.h./age)	0.85	0.72	0.023
Y = 0.25339 + 0.15320 (weighted sp. gr., 1 core) — 0.16267 (d.b.h./age)	0.85	0.72	0.022
Y = 0.28129 + 0.48540 (sp. gr., outer 1/3 of 2 extracted cores) — 0.18545 (d.b.h./age)	0.85	0.72	0.023
Y = 0.29534 + 0.47166 (sp. gr., outer 2/3 of 1 extracted core) — 0.20431 (d.b.h./age)	0.85	0.72	0.023
Y = 0.26601 + 0.47977 (sp. gr., outer 2/3 of 1 core) — 0.16456 (d.b.h./age)	0.85	0.72	0.022
Y = 0.05421 + 0.85125 (weighted sp. gr., 2 cores)	0.84	0.71	0.023
Y = 0.29517 + 0.45357 (sp. gr., 1 core) — 0.19764 (d.b.h./age)	0.84	0.71	0.023
Y = 0.29764 + 0.47477 (weighted sp. gr., 1 extracted core) — 0.20687 (d.b.h./age)	0.84	0.71	0.023
Y = 0.35317 + 0.33339 (sp. gr., outer 1/3 of 1 core) — 0.16763 (d.b.h./age) — 0.00204 (d.b.h.)	0.84	0.71	0.023
Y = 0.10027 + 0.73661 (sp. gr., outer 1/3 of 2 cores)	0.83	0.69	0.024
Y = 0.32596 + 0.43207 (sp. gr., 1 extracted core) — 0.22388 (d.b.h./age)	0.83	0.69	0.024
Y = 0.32514 + 0.35852 (sp. gr., outer 1/3 of 1 core) — 0.17372 (d.b.h./age)	0.83	0.69	0.024
Y = 0.37669 + 0.30488 (sp. gr., outer 1/3 of 1 extracted core) — 0.21307 (d.b.h./age) — 0.00065 (merch. vol.)	0.83	0.69	0.024
Y = 0.36179 + 0.32489 (sp. gr., outer 1/3 of 1 extracted core) — 0.21737 (d.b.h./age)	0.81	0.66	0.025
Y = 0.02762 + 0.96834 (sp. gr., outer 2/3 of 2 extracted cores)	0.79	0.62	0.026
Y = 0.07598 + 0.81345 (weighted sp. gr., 1 core)	0.77	0.59	0.027
Y = 0.09291 + 0.76550 (sp. gr., outer 2/3 of 1 core)	0.76	0.58	0.027
Y = 0.02672 + 0.98552 (weighted sp. gr., 2 extracted cores)	0.76	0.58	0.027
Y = 0.06759 + 0.85070 (sp. gr., 2 cores)	0.76	0.58	0.027
Y = 0.15778 + 0.62766 (sp. gr., outer 1/3 of 1 core)	0.73	0.53	0.029
Y = 0.09957 + 0.79651 (sp. gr., outer 1/3 of 2 extracted cores)	0.72	0.52	0.030
Y = 0.06341 + 0.93478 (sp. gr., 2 extracted cores)	0.68	0.46	0.031
Y = 0.10591 + 0.77028 (sp. gr., 1 core)	0.68	0.46	0.031
Y = 0.11900 + 0.76519 (sp. gr., outer 2/3 of 1 extracted core)	0.66	0.44	0.032
Y = 0.11205 + 0.79290 (weighted sp. gr., 1 extracted core)	0.65	0.42	0.032
Y = 0.18626 + 0.60863 (sp. gr., outer 1/3 of 1 extracted core)	0.59	0.35	0.034
Y = 0.15212 + 0.72256 (sp. gr., 1 extracted core)	0.57	0.32	0.035

Table 7.—*Regression equations, correlation coefficients, coefficients of determination, and standard errors for Choctawhatchee sand pine increment core tree specific gravity relationships*

Regression equations	r	r^2	Standard error
Tree specific gravity (Y):			
Y = 0.15157 + 0.63382 (weighted sp. gr., 2 cores) + 0.00058 (total height) — 0.07528 (d.b.h./age)	0.76	0.58	0.019
Y = 0.15281 + 0.75759 (sp. gr., 2 extracted cores) + 0.01208 (total height/age) — 0.07933 (d.b.h./age)	0.76	0.58	0.019
Y = 0.13286 + 0.63717 (sp. gr., outer 2/3 of 2 cores) + 0.00067 (total height) — 0.02309 (merch. vol.)	0.76	0.58	0.019
Y = 0.14315 + 0.74310 (weighted sp. gr., 2 extracted cores)	0.75	0.56	0.019
Y = 0.14414 + 0.67089 (sp. gr., outer 2/3 of 2 cores)	0.75	0.56	0.019
Y = 0.17296 + 0.63733 (weighted sp. gr., 2 cores) — 0.04144 (d.b.h./age)	0.75	0.56	0.020
Y = 0.14879 + 0.78915 (sp. gr., 2 extracted cores) — 0.05552 (d.b.h./age)	0.75	0.56	0.020
Y = 0.13074 + 0.74825 (weighted sp. gr., 2 extracted cores) + 0.00019 (total height)	0.75	0.56	0.020
Y = 0.12917 + 0.67696 (sp. gr., outer 2/3 of 2 cores) + 0.00022 (total height)	0.75	0.56	0.019
Y = 0.14328 + 0.71956 (weighted sp. gr., 2 extracted cores) + 0.00037 (total height) — 0.04045 (d.b.h./age)	0.75	0.56	0.020
Y = 0.12072 + 0.82265 (sp. gr., 2 extracted cores)	0.74	0.55	0.020
Y = 0.15089 + 0.66158 (weighted sp. gr., 2 cores)	0.74	0.55	0.020
Y = 0.15030 + 0.71946 (sp. gr., outer 2/3 of 2 extracted cores)	0.74	0.55	0.020
Y = 0.13916 + 0.72383 (sp. gr., outer 2/3 of 2 extracted cores) + 0.00017 (total height)	0.74	0.55	0.020
Y = 0.14988 + 0.69963 (sp. gr., outer 2/3 of 2 extracted cores) + 0.00032 (total height) — 0.03215 (d.b.h./age)	0.74	0.55	0.020
Y = 0.20686 + 0.55197 (sp. gr., 2 cores) + 0.00074 (total height) — 0.15249 (d.b.h./age)	0.72	0.52	0.021
Y = 0.18347 + 0.65460 (sp. gr., 1 extracted core) + 0.00074 (total height) — 0.00252 (d.b.h.)	0.71	0.50	0.021
Y = 0.23834 + 0.54820 (sp. gr., 2 cores) — 0.10984 (d.b.h./age)	0.70	0.49	0.021
Y = 0.20125 + 0.68069 (sp. gr., 1 extracted core) — 0.00147 (d.b.h.)	0.69	0.48	0.021
Y = 0.23117 + 0.43776 (sp. gr., outer 1/3 of 2 cores) + 0.00075 (total height) — 0.00135 (d.b.h.)	0.68	0.46	0.022
Y = 0.16588 + 0.72651 (sp. gr., 1 extracted core)	0.67	0.45	0.022
Y = 0.24326 + 0.46630 (sp. gr., outer 1/3 of 2 cores)	0.67	0.45	0.022
Y = 0.21625 + 0.47955 (sp. gr., outer 1/3 of 2 cores) + 0.00038 (total height)	0.67	0.45	0.022
Y = 0.24007 + 0.47387 (sp. gr., 1 core) + 0.00073 (total height) — 0.12213 (d.b.h./age)	0.67	0.45	0.022
Y = 0.23404 + 0.46162 (sp. gr., outer 1/3 of 2 extracted cores) + 0.00066 (total height) — 0.02153 (merch. vol./age)	0.67	0.45	0.022
Y = 0.24808 + 0.40972 (sp. gr., outer 2/3 of 1 core) + 0.00100 (total height) — 0.00259 (d.b.h.)	0.67	0.45	0.022
Y = 0.23105 + 0.40972 (sp. gr., outer 1/3 of 2 extracted cores) + 0.00025 (total height)	0.66	0.44	0.022
Y = 0.25014 + 0.41073 (weighted sp. gr., 1 core) + 0.00098 (total height) — 0.00256 (d.b.h.)	0.66	0.44	0.022
Y = 0.24822 + 0.49188 (sp. gr., outer 1/3 of 2 extracted cores)	0.66	0.44	0.022
Y = 0.20767 + 0.55582 (sp. gr., 2 cores)	0.64	0.41	0.022
Y = 0.27102 + 0.47048 (sp. gr., 1 core) — 0.08025 (d.b.h./age)	0.64	0.41	0.023
Y = 0.28251 + 0.42026 (sp. gr., outer 2/3 of 1 core) — 0.00120 (d.b.h.)	0.64	0.41	0.022
Y = 0.28262 + 0.42307 (weighted sp. gr., 1 core) — 0.00119 (d.b.h.)	0.63	0.40	0.023
Y = 0.25036 + 0.46742 (weighted sp. gr., 1 extracted core) + 0.00081 (total height) — 0.00237 (d.b.h.)	0.63	0.40	0.023
Y = 0.25050 + 0.45745 (sp. gr., outer 2/3 of 1 extracted core) + 0.00084 (total height) — 0.00237 (d.b.h.)	0.62	0.38	0.023
Y = 0.25307 + 0.45416 (sp. gr., outer 2/3 of 1 core)	0.62	0.38	0.023
Y = 0.23899 + 0.49636 (sp. gr., 1 core)	0.61	0.37	0.023
Y = 0.25274 + 0.45823 (weighted sp. gr., 1 core)	0.61	0.37	0.023
Y = 0.27071 + 0.49236 (weighted sp. gr., 1 extracted core) — 0.00121 (d.b.h.)	0.61	0.37	0.024
Y = 0.27218 + 0.48172 (sp. gr., outer 2/3 of 1 extracted core) — 0.00117 (d.b.h.)	0.60	0.36	0.024
Y = 0.23779 + 0.53751 (weighted sp. gr., 1 extracted core)	0.59	0.35	0.024
Y = 0.23935 + 0.52709 (sp. gr., outer 2/3 of 1 extracted core)	0.58	0.34	0.024
Y = 0.33900 + 0.22788 (sp. gr., outer 1/3 of 1 core) + 0.00101 (total height) — 0.00291 (d.b.h.)	0.56	0.31	0.025
Y = 0.37332 + 0.23890 (sp. gr., outer 1/3 of 1 core) — 0.00148 (d.b.h.)	0.52	0.27	0.025
Y = 0.35424 + 0.22237 (sp. gr., outer 1/3 of 1 extracted core) + 0.00094 (total height) — 0.00291 (d.b.h.)	0.52	0.27	0.025
Y = 0.34021 + 0.27374 (sp. gr., outer 1/3 of 1 core)	0.49	0.24	0.026
Y = 0.38213 + 0.24146 (sp. gr., outer 1/3 of 1 extracted core) — 0.00155 (d.b.h.)	0.49	0.24	0.026
Y = 0.34619 + 0.28389 (sp. gr., outer 1/3 of 1 extracted core)	0.45	0.20	0.026

Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part III--Table-Mountain Pine (*Pinus pungens* Lamb.)



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Alexander Clark III and
Joseph R. Saucier

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Asheville, North Carolina
U.S. Department of Agriculture
Forest Service

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Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part III--Table-Mountain Pine (Pinus pungens Lamb.)

by

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and
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INTRODUCTION

This report is the third in a series covering the wood density surveys of the minor species of yellow pine in the Eastern United States.[1] Literature review and historical information regarding these surveys were presented in "Part I—Spruce Pine (*Pinus glabra* Walt.)" by Taras and Saucier (1968) and will not be repeated here.

The objectives of the survey were:

(1) To obtain data that will provide an estimate of the average specific gravity of unextracted and extracted wood of each minor species, and establish the degree of variation about each mean.

(2) To evaluate increment core/tree specific gravity relationships and develop regression equations for predicting tree specific gravity from increment core specific gravity.

(3) To examine the geographic trends of wood specific gravity within the range of each species, from east to west and from north to south.

MATERIALS AND METHODS

Species

Table-Mountain pine (*Pinus pungens* Lamb.) has been of little commercial importance, but with greater demands for wood it is becoming increasingly important in some localities for pulpwood and lumber. It generally grows on poor, dry, rocky slopes as a small, stunted tree with a low, flat crown, and reaches 40 to 65 feet in height and 15 to 20 inches in diameter (fig. 1A). The needles of Table-Mountain pine are about 2 to 3 inches long, dark yellow-green, rigid and often twisted, and grow in fascicles of two (fig. 1B). Cones are often clustered, in pairs or in whorls of 5 to 7, and are 2 to 3-1/2 inches long, ovoid, sessile, heavy, and persist for many years. Cone scales have thickened ends and are armed with conspicuous, sharp, hooked spurs. The scientific name *pungens*, from the Latin *pungere* meaning to sting or prick, refers to the sharp spurs on the end of the cone scales (fig. 1C). The bark on older trees is up to 1 inch thick, reddish-brown, and forms plates with small, thin, superficial scales (fig. 1D).

The range of Table-Mountain pine extends from the mountains of central Pennsylvania and eastern West Virginia, south through the mountains of Virginia, North Carolina, Tennessee, and South Carolina into the mountains of north Georgia (fig. 2). This species is found in extensive pure

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[1] This study was conducted in cooperation with the Forest Products Laboratory, the Northeastern Forest Experiment Station, the Southern Forest Experiment Station, and state forestry services, the pulp and paper industries, the southern pine plywood and sawmill industry, and numerous private forest owners throughout the Southern and Eastern United States.

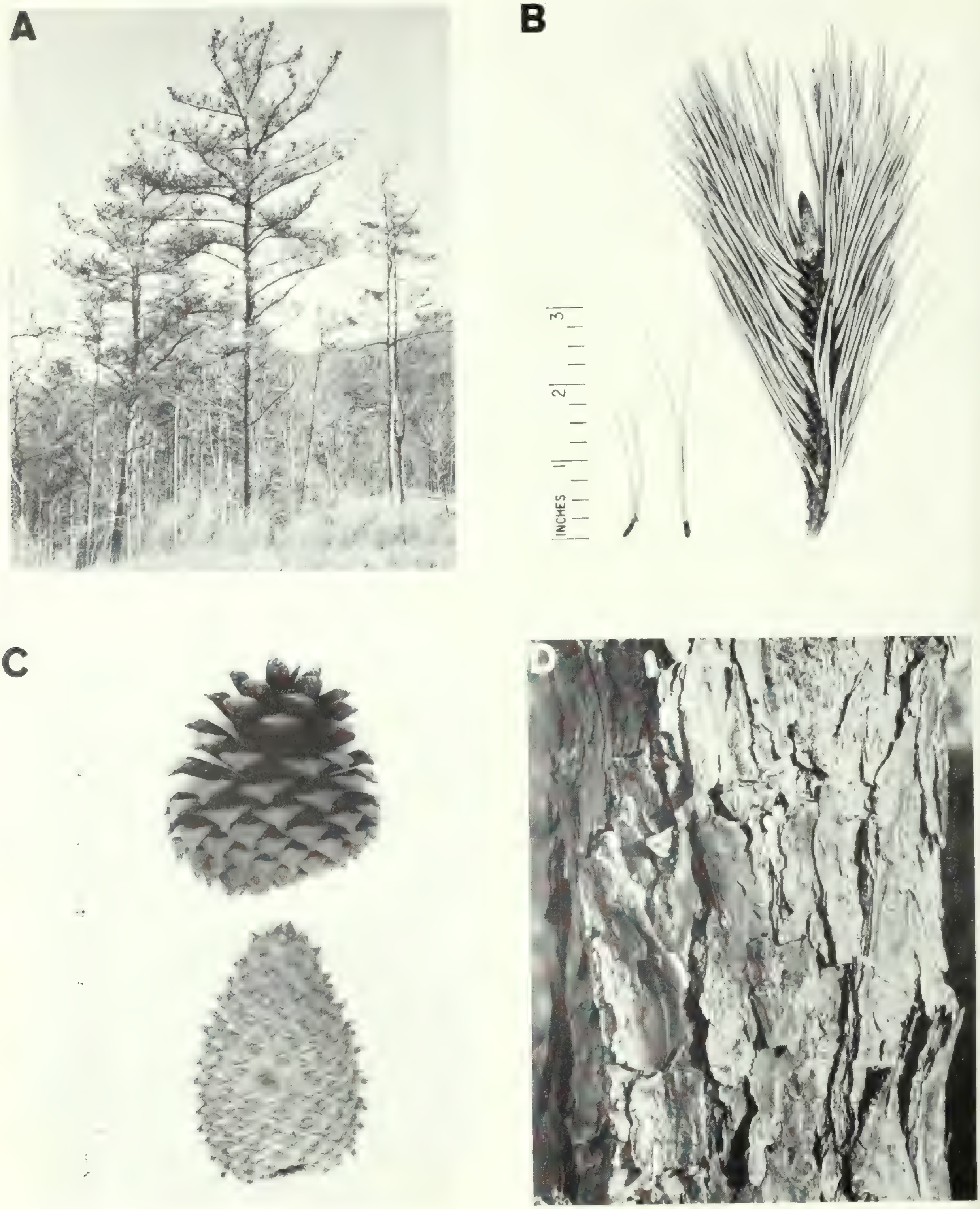

Figure 1.—*Botanical features of Table-Mountain pine: (A) mature tree, (B) needles, (C) open and closed cones, and (D) bark.*

stands suitable for timber production in the southern part of its range on the table lands of the Appalachian Mountains; hence, its common name "Table-Mountain pine." This species is also known locally as hickory pine, mountain pine, prickly pine, bull pine, and poverty pine.

Field Sampling Procedure

To meet objectives of the study, 50 plots were sampled throughout the range of Table-Mountain pine. We calculated the number of trees sampled had to be 15, in order to obtain an estimate of the mean wood density with a 95-percent confidence interval width of .02. The plots were selected randomly, with replacement, with the probability roughly proportioned to the commercial forest area within Forest Survey Units[2] containing Table-Mountain pine. A 6-mile grid system was used to locate plots randomly within survey units.

At each plot location, a random azimuth was selected along which the first 15 trees, over 5.0 inches d.b.h. and showing no signs of heartrot, were sampled by removing two increment cores from opposite sides of each tree. Total height, merchantable height to a 4-inch top, and d.b.h. of each sample tree were recorded.

The trees to be used for analyzing increment core/tree specific gravity relationships were randomly selected at four locations within the range of Table-Mountain pine (fig. 2). Two increment cores were taken from each of 25 trees at each location before they were felled. Beginning at the butt end of the tree, 1-inch-thick disks were cut at 5-foot intervals to a 4-inch top. Total height and merchantable height to a 4-inch top were recorded, along with diameter of each disk.

Laboratory Procedures

The specific gravity of all unextracted and extracted increment cores was determined with the maximum moisture method described by Smith (1954). The specific gravity of the wood disks was determined by the buoyancy method (Heinrichs 1954) and is based on green volume and ovendry weight.

Increment cores from all trees were extracted after unextracted specific gravity was determined. These extractions were made with a mixture of two parts benzene and one part ethyl alcohol. Following extraction for 24 hours, the cores were dried, saturated with water, and their specific gravity was determined by the maximum moisture method. No wood disks were extracted.

The increment cores from the trees collected to analyze increment core/tree specific gravity relationships were each divided into three equal parts, and the specific gravity of each segment was determined. The purpose was to obtain a weighted increment core specific gravity and to examine the relationship of parts of whole increment cores (1/3 and 2/3 only) to total tree specific gravity. Weighted total core specific gravity was determined by weighting the specific gravities of segments by the cross-sectional areas the segments represented.

The average specific gravity of the individual 5-foot bolts within each tree was computed as the mean of the bolt's terminal disks. The average specific gravity of the tree was determined by weighting the average bolt specific gravity by bolt volume. Formulas for all these computations are shown in the Appendix. A discussion of the analysis of the increment core/tree specific gravity relationship data is presented in an office report available from the Forestry Sciences Laboratory, Carlton Street, Athens, Georgia 30601.

RESULTS AND DISCUSSION

Table-Mountain Pine Specific Gravity and Its Variation

The average specific gravity of *unextracted* Table-Mountain pine increment cores was .470, based on the average of two whole increment cores from 750 sample trees collected over the entire range of the species. The standard error of the mean increment core specific gravity was .005, and the standard deviation of the individual observations about the mean was .033.

The average specific gravity of *extracted* increment cores was .437; standard error was .004 and standard deviation of individuals was .027. The specific gravity of unextracted cores was 7.5 percent higher than

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[2] Forest Survey Units are subdivisions of a state based in part on county boundaries and in part on physiography of the state. They are established for the purpose of sampling and reporting results efficiently.

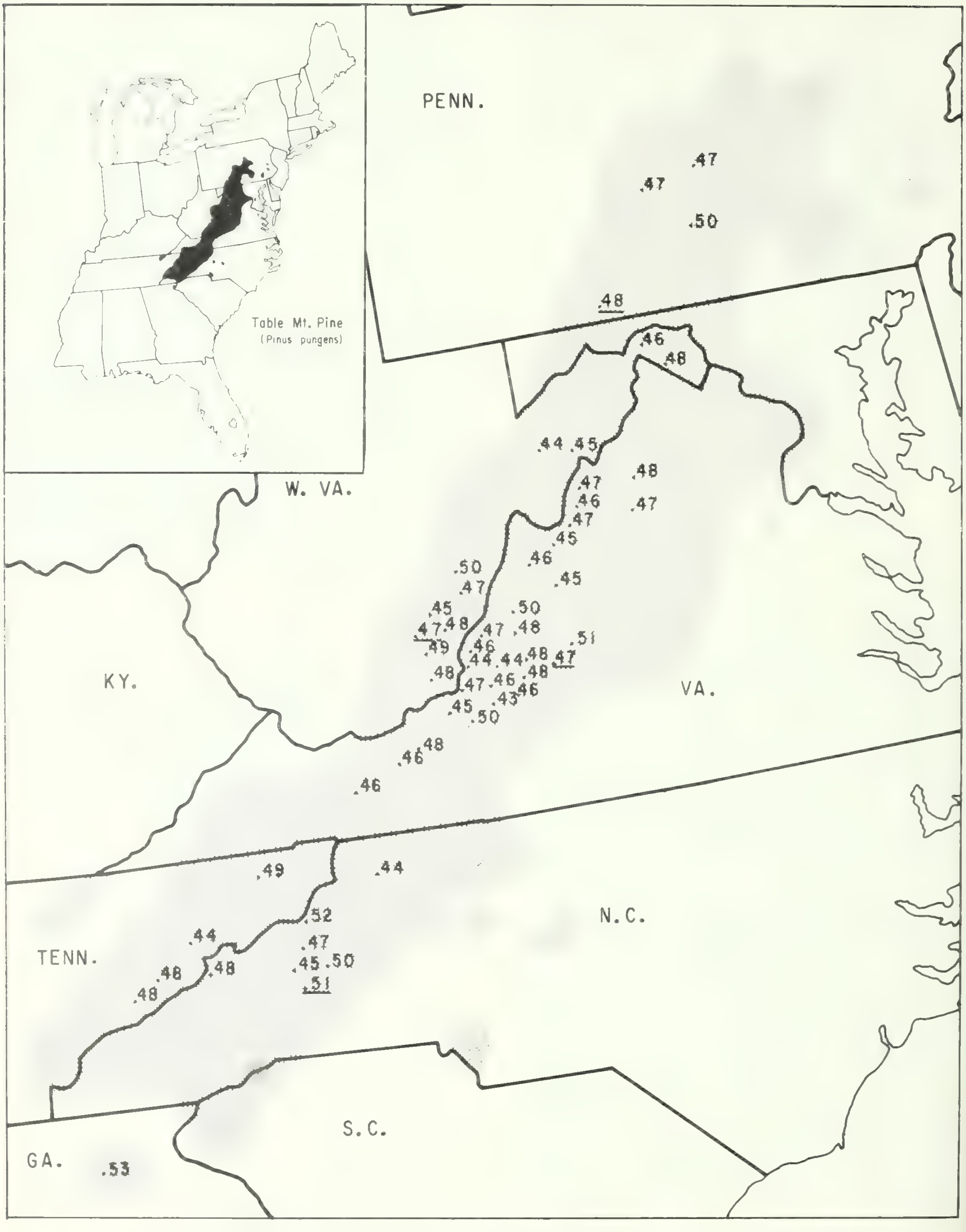

Figure 2.—*Range of Table-Mountain pine. Numbers indicate the average increment core specific gravity for sample plots at the respective locations. Underlined numbers indicate plots where samples were collected for increment core/tree specific gravity relationships.*

extracted core specific gravity. This is comparable to the 6.0 to 7.5 percent difference reported for the four major southern yellow pines and spruce pine (Taras and Saucier 1967, 1968), but is considerably below the 9.7 percent difference reported for Choctawhatchee sand pine (Clark and Taras 1969). Table 1 shows the average specific gravity of *unextracted* and *extracted* increment cores, and also includes the average d.b.h., age, and percentage difference resulting from extraction for each plot.

The estimated average tree specific gravities for Table-Mountain pine were obtained by using the following regression equation:

$$\text{Tree specific gravity } (Y) = 0.21263 + 0.66448 \text{ (sp. gr., 2 extracted cores)} - 0.10861 \text{ (d.b.h./age)} \qquad (1)$$

Table 1.—*Specific gravity of unextracted and extracted increment cores from Table-Mountain pine*

Plot number	County and state	Trees in sample	Mean d.b.h.	Mean age	Unextracted		Extracted		Difference between means
					Mean and standard error	Standard deviation	Mean and standard error	Standard deviation	
		Number	*Inches*	*Years*					*Percent*
1	Mifflin, Pa.	15	9.3	54	.467 (.013)	.051	.431 (.007)	.027	8.35
2	Huntington, Pa.	15	9.6	49	.466 (.006)	.024	.425 (.005)	.020	9.65
3	Perry, Pa.	15	8.6	71	.504 (.006)	.022	.463 (.005)	.020	8.86
4	Berkeley, W. Va.	15	10.3	41	.481 (.007)	.026	.426 (.008)	.032	12.91
5	Morgan, W. Va.	15	10.3	45	.459 (.007)	.028	.426 (.008)	.030	7.75
6	Hardy, W. Va.	15	7.2	49	.447 (.012)	.045	.428 (.006)	.021	4.44
7	Page, Va.	15	9.7	55	.481 (.009)	.033	.439 (.007)	.028	9.57
8	Page, Va.	15	7.3	43	.471 (.008)	.031	.445 (.007)	.026	5.84
9	Botetourt, Va.	15	7.1	38	.463 (.009)	.036	.441 (.008)	.030	4.99
10	Botetourt, Va.	15	6.4	27	.431 (.007)	.027	.419 (.007)	.026	2.86
11	Botetourt, Va.	15	9.0	57	.459 (.008)	.032	.428 (.008)	.029	7.24
12	Botetourt, Va.	15	6.7	28	.442 (.012)	.045	.413 (.008)	.029	7.02
13	Botetourt, Va.	15	11.0	92	.483 (.006)	.022	.437 (.006)	.024	10.53
14	Botetourt, Va.	15	7.8	58	.478 (.008)	.029	.440 (.006)	.025	8.64
15	Amherst, Va.	15	9.2	56	.510 (.006)	.024	.480 (.005)	.019	6.25
16	Craig, Va.	15	6.4	60	.456 (.009)	.034	.427 (.007)	.026	6.79
17	Craig, Va.	15	10.2	90	.497 (.004)	.016	.447 (.005)	.020	11.19
18	Wythe, Va.	15	7.5	46	.459 (.005)	.020	.423 (.005)	.018	8.51
19	Pulaski, Va.	15	7.6	37	.459 (.006)	.024	.429 (.006)	.023	6.99
20	Montgomery, Va.	15	9.3	55	.478 (.006)	.023	.449 (.005)	.020	6.46
21	Craig, Va.	15	7.6	37	.450 (.004)	.016	.423 (.004)	.015	6.38
22	Craig, Va.	15	6.1	35	.472 (.005)	.018	.446 (.005)	.019	5.83
23	Craig, Va.	15	7.1	29	.442 (.008)	.030	.419 (.008)	.029	5.49
24	Alleghany, Va.	15	8.9	80	.472 (.011)	.042	.441 (.010)	.037	7.03
25	Alleghany, Va.	15	8.0	39	.478 (.008)	.031	.445 (.009)	.033	7.42
26	Bath, Va.	15	9.1	72	.503 (.005)	.020	.465 (.004)	.015	8.17
27	Augusta, Va.	15	8.7	58	.446 (.008)	.029	.407 (.007)	.026	9.58
28	Augusta, Va.	15	8.7	69	.456 (.005)	.019	.414 (.005)	.020	10.14
29	Augusta, Va.	15	9.3	55	.452 (.007)	.026	.416 (.009)	.033	8.65
30	Rockingham, Va.	15	7.4	51	.465 (.007)	.026	.425 (.007)	.026	9.41
31	Rockingham, Va.	15	9.7	55	.456 (.009)	.033	.417 (.006)	.022	9.35
32	Rockingham, Va.	15	9.0	71	.471 (.007)	.027	.436 (.008)	.030	8.03
33	Grant, W. Va.	15	8.4	48	.444 (.010)	.039	.419 (.007)	.029	5.97
34	Pocahontas, W. Va.	15	9.6	66	.500 (.007)	.029	.470 (.006)	.024	6.38
35	Pocahontas, W. Va.	15	11.4	47	.466 (.006)	.024	.426 (.005)	.019	9.39
36	Greenbrier, W. Va.	15	6.2	31	.446 (.005)	.021	.420 (.005)	.018	6.19
37	Greenbrier, W. Va.	15	9.9	74	.485 (.008)	.032	.453 (.007)	.027	7.06
38	Greenbrier, W. Va.	15	11.0	90	.480 (.006)	.023	.441 (.006)	.023	8.84
39	Monroe, W. Va.	15	6.7	40	.477 (.003)	.013	.446 (.004)	.015	6.95
40	Sullivan, Tenn.	15	9.1	51	.486 (.008)	.030	.462 (.007)	.027	5.19
41	Green, Tenn.	15	5.7	20	.444 (.006)	.024	.428 (.006)	.025	3.74
42	Cocke, Tenn.	15	12.3	53	.476 (.007)	.028	.429 (.006)	.025	10.96
43	White, Ga.	15	7.5	39	.526 (.006)	.024	.479 (.008)	.033	9.81
44	Wilkes, N. C.	15	8.3	23	.443 (.005)	.018	.417 (.006)	.023	6.24
45	Caldwell, N. C.	15	9.0	54	.517 (.011)	.042	.477 (.008)	.031	8.39
46	Burke, N. C.	15	7.8	45	.498 (.007)	.027	.459 (.009)	.034	8.50
47	Burke, N. C.	15	8.1	32	.470 (.008)	.033	.441 (.006)	.025	6.58
48	McDowell, N. C.	15	6.4	25	.448 (.008)	.032	.421 (.006)	.024	6.41
49	Green, Tenn.	15	6.9	31	.477 (.010)	.040	.442 (.011)	.041	7.92
50	Madison, N. C.	15	7.0	43	.483 (.008)	.029	.454 (.007)	.028	6.39
	Total	750	8.4	50	.470 (.005)	.033	.437 (.004)	.027	7.55

When the specific gravity of 750 trees sampled by increment cores was adjusted to whole tree specific gravity by using equation (1), the average tree specific gravity was .485, with a standard error of .002.

In general, the specific gravity of unextracted increment cores taken at d.b.h. from the major southern yellow pines, spruce pine, and sand pine has been reported to be higher than the weighted specific gravity of the whole tree (Clark and Taras 1969; Taras and Saucier 1968; U. S. Forest Service 1965). This is not the case with Table-Mountain pine, however, for its weighted tree specific gravity was 3.1 percent higher than its increment core specific gravity. Because Table-Mountain pine is a short, stunted tree with a large amount of taper, weighting the average bolt specific gravity by bolt volume possibly caused the weighted tree specific gravity to be higher than the increment core specific gravity. Another possible explanation might be that there is a smaller proportion of juvenile wood with low specific gravity in the upper portion of the Table-Mountain bole than in the faster-growing southern yellow pines.

The specific gravity of unextracted increment cores and the estimated tree specific gravity by three diameter classes (5.0 to 8.9 inches; 9.0 to 14.9 inches; and 15.0+ inches) are presented in table 2 for each Forest Survey Unit sampled.

The data in tables 1 and 2 are shown in figures 2 and 3 to illustrate specific gravity changes with geographic location. There were no east-west or north-south trends in increment core specific gravity. The relative uniformity of specific gravity over the entire range may be associated with the restricted site conditions where Table-Mountain pine grows—mainly on poor, rocky slopes at high elevations where moisture is the main factor limiting annual growth. The major southern yellow pines grow on a variety of sites and show geographic trends in specific gravity resulting from regional environmental conditions. The small differences in specific gravity which occur between plots and among trees within a plot were statistically significant at the .01 probability level (table 3). The specific gravities of unextracted and extracted increment cores from Table-Mountain pine vary more between plots than among trees within a plot, as was found for spruce pine by Clark and Ike (1969).

Increment Core / Tree Specific Gravity Relationships - Simple Linear and Multiple Regression Analyses

A discussion of the increment core/tree specific gravity relationships is given in an office report available upon request, and will not be treated in detail here. All the regression equations developed from these data for predicting tree specific gravity of Table-Mountain pine are in table 4 in the Appendix.

From these data, the best equation developed for predicting tree specific gravity of Table-Mountain pine was:

$$Y = 0.20620 + 0.62612 \text{ (weighted sp. gr., 2 cores)} - 0.02143 \text{ (total height/age)} - 0.03006 \text{ (merch. vol./age)} \qquad (2)$$

This equation had a correlation coefficient of .82 and accounted for 67 percent of the variation about regression.

Equation (1) was used in this study to adjust specific gravity of Table-Mountain pine increment cores to tree specific gravity. This equation was used instead of the best one developed because of the time and increased cost involved in obtaining weighted specific gravity values for segmented cores. Equation (1) had a correlation coefficient of .78 and accounted for 61 percent of the variation about regression, which is 6 percent less than accounted for by the best equation.

Relationship of Unextracted and Extracted Specific Gravity

The specific gravity of all increment cores was determined in both the unextracted and extracted condition. From these data, a regression equation for predicting extracted specific gravity from unextracted specific gravity was developed. Equation (3) has a correlation coefficient of .87.

$$Y = 0.08523 + 0.74797 X_1 \qquad (3)$$

Where Y = specific gravity of 2 extracted increment cores
X_1 = specific gravity of 2 unextracted increment cores

A similar high correlation of $r = .88$ was reported for the specific gravity relationship between unextracted and extracted increment cores in spruce pine (Taras and Saucier 1968) and in Ocala and Choctawhatchee races of sand pine (Clark and Taras 1969).

Table 2.—*Specific gravity for Table-Mountain pine by states and by Forest Survey Units within states*

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Unextracted increment core specific gravity		Estimated tree specific gravity[1] mean and standard error
				Mean and standard error	Standard deviation	
	Number	*Inches*	*Number*			
Georgia						
Northern (5)	1	5.0-8.9	11	.518 (.008)	.026	.506 (.010)
		9.0-14.9	4	.545 (.004)	.008	.520 (.017)
		15.0+	0	0	0	0
North Carolina						
Mountain (4)	6	5.0-8.9	64	.475 (.009)	.041	.486 (.004)
		9.0-14.9	26	.481 (.021)	.050	.475 (.008)
		15.0+	0	0	0	0
Pennsylvania						
South-central (6)	3	5.0-8.9	23	.483 (.010)	.042	.488 (.007)
		9.0-14.9	22	.475 (.016)	.032	.484 (.007)
		15.0+	0	0	0	0
Tennessee						
Eastern (5)	4	5.0-8.9	38	.467 (.013)	.037	.484 (.006)
		9.0-14.9	20	.478 (.003)	.028	.474 (.008)
		15.0+	2	.464 (.001)	.003	.457 (.023)
Virginia						
Northern Piedmont (3)	1	5.0-8.9	9	.508 (.009)	.028	.515 (.011)
		9.0-14.9	5	.513 (.006)	.014	.512 (.014)
		15.0+	1	.508 (—)	—	.508 (—)
Northern Mountain (4)	22	5.0-8.9	219	.461 (.004)	.027	.480 (.002)
		9.0-14.9	108	.471 (.005)	.031	.481 (.003)
		15.0+	3	.495 (.028)	.068	.486 (.018)
Southern Mountain (5)	3	5.0-8.9	32	.464 (.007)	.026	.480 (.006)
		9.0-14.9	13	.470 (.004)	.020	.483 (.009)
		15.0+	0	0	0	0
State total	26	5.0-8.9	260	.463 (.001)	.028	.482 (.002)
		9.0-14.9	126	.473 (.001)	.031	.482 (.003)
		15.0+	4	.498 (.001)	.056	.490 (.016)
West Virginia						
Northeastern (2)	6	5.0-8.9	41	.461 (.013)	.040	.485 (.005)
		9.0-14.9	47	.471 (.007)	.029	.477 (.005)
		15.0+	2	.445 (.001)	.002	.458 (.023)
Southern (3)	4	5.0-8.9	41	.467 (.010)	.032	.485 (.005)
		9.0-14.9	17	.484 (.007)	.024	.493 (.008)
		15.0+	2	.455 (.010)	.021	.474 (.022)
State total	10	5.0-8.9	82	.464 (.005)	.039	.486 (.003)
		9.0-14.9	64	.475 (.002)	.029	.480 (.004)
		15.0+	4	.450 (.005)	.012	.464 (.016)
All States	50	5.0-8.9	478	.467 (.005)	.032	.485 (.001)
		9.0-14.9	262	.476 (.006)	.038	.480 (.003)
		15.0+	10	.472 (.012)	.037	.473 (.010)
Total all classes	50		750	.470 (.005)	.033	.485 (.002)

[1] Estimates were made with equation (1): $Y = 0.21263 + 0.66448$ (sp. gr., 2 extracted cores) $- 0.10861$ (d.b.h./age).

Table 3.—*Analyses of variance for Table-Mountain pine specific gravity and test of significance for locations and trees within a location*

Source	d.f.	Unextracted		Extracted	
		MS	F ratio	MS	F ratio
Among locations	49	0.0137	8.05**	0.0100	7.69**
Among trees within locations	700	0.0017	4.25**	0.0013	4.33**
Among cores within trees	750	0.0004		0.0003	
Total	1499				

**Significant at the .01 probability level.

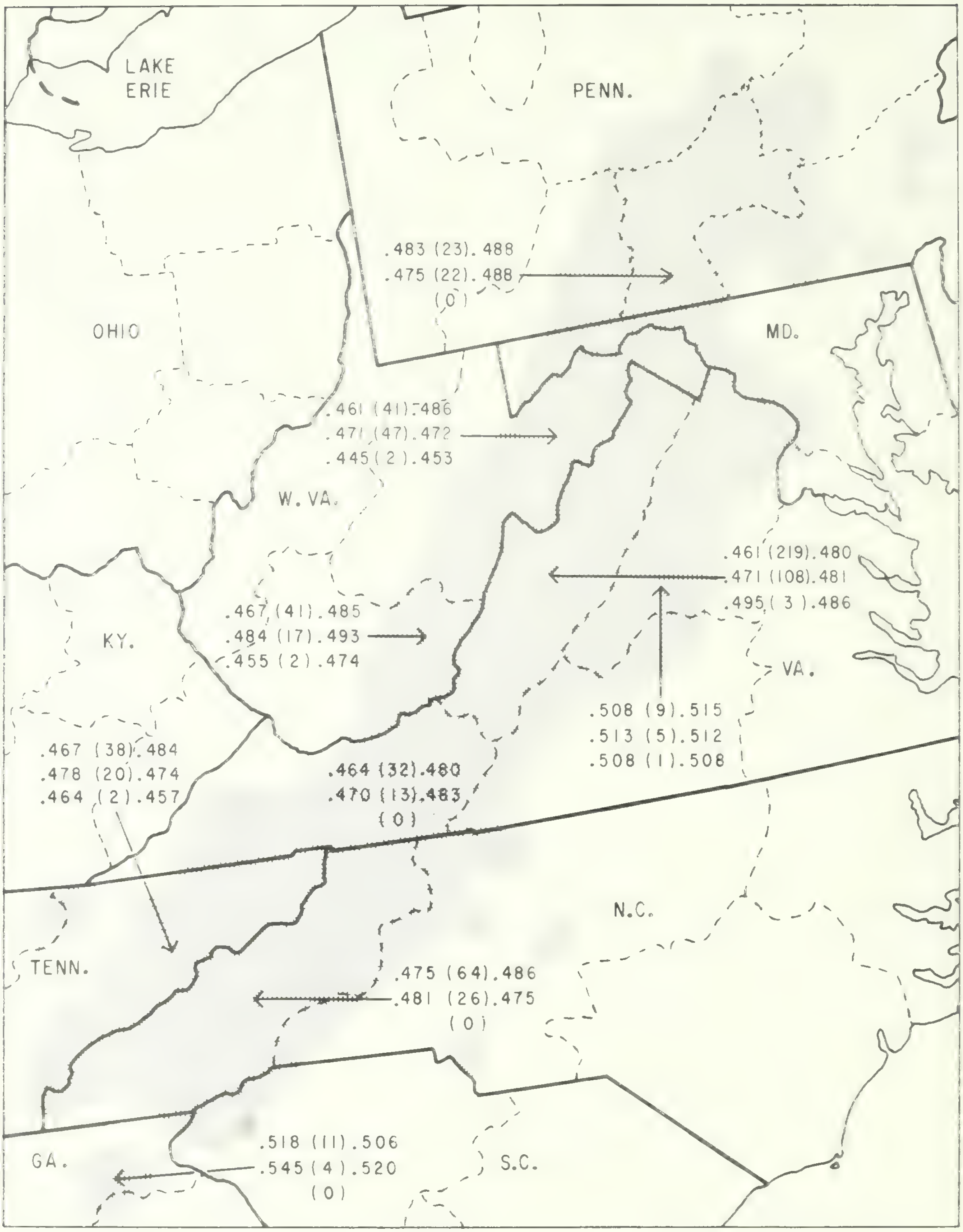

Figure 3.—*Average estimated tree specific gravity and increment core specific gravity by diameter classes in each Forest Survey Unit. The number on the left is the increment core specific gravity; the number of trees sampled is is in parentheses; the number on the right is the estimated tree specific gravity. The top row of values represents the 5.0 to 8.9 inch class, the second row represents the 9.0 to 14.9 inch class, and the bottom row represents the 15.0+ inch class.*

SUMMARY AND CONCLUSIONS

The average specific gravity of Table-Mountain pine increment cores taken at d.b.h. was .470. After the extractives were removed, the same increment cores had an average specific gravity of .437, a difference of 7.5 percent.

The best equation developed for predicting Table-Mountain pine tree specific gravity involved three independent variables: (1) weighted specific gravity of 2 cores; (2) total height/age; and (3) merchantable volume/age. These variables explained 67 percent of the variation. Since the increment cores taken in the survey were not segmented when their specific gravity was determined, equation (1) was used to adjust Table-Mountain pine increment core specific gravity to tree specific gravity, and accounted for 61 percent of the variation about regression.

Equation (3) was developed for predicting extracted increment core specific gravity from unextracted increment core specific gravity, and accounted for 76 percent of the total variation in extracted increment core specific gravity. There appear to be no distinct north-south or east-west geographic trends in specific gravity within the range of the species.

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APPENDIX

Computational Procedures

1. Increment core specific gravity $= \dfrac{\text{ovendry weight of core}}{\text{green weight of core} - .3464\,(\text{ovendry weight of core})}$

2. Disk specific gravity $= \dfrac{\text{ovendry weight of disk}}{\text{displaced volume of disk}}$

3. Bolt specific gravity $= \dfrac{\text{specific gravity top disk} + \text{specific gravity bottom disk}}{2}$

4. Tree specific gravity $= \dfrac{\sum\limits_{1-n} (\text{bolt volume} \times \text{bolt specific gravity})}{\sum\limits_{1-n} \text{bolt volumes}}$

5. Bolt volume = bolt length, feet $\times \left[\dfrac{.005454\,(\text{d.i.b.})_t^2 + .005454\,(\text{d.i.b.})_b^2}{2} \right]$

   where: t = top of bolt
   b = base of bolt

6. (a) Mean core specific gravity $\bar{x} = \dfrac{\Sigma_i \Sigma_j X_{ij}}{m_1 n_1}$

   where: X_{ij} = the core specific gravity for the jth tree at the ith location
   m_1 = number of trees at each location
   n_1 = number of locations

   (b) The standard deviation of individuals was estimated from the sample range of the core specific gravities using the tabular values of the ratio of the standard deviation to the range.

7. Tree specific gravities were estimated from regression by:

   (a) Tree specific gravity (Y) $= b_0 + b_1X_1 + b_2X_2$

   where: Y = tree specific gravity
   X_1 = average specific gravity of 2 extracted cores
   X_2 = d.b.h./age

   (b) The standard error of the predicted mean tree specific gravity was estimated by--

$$S_{\hat{y}} \quad \left[S_y^2 \times \left(\frac{1}{m_2 n_2} + C_{11}(\bar{x}_{1,1} - \bar{x}_{1,2})^2 + C_{22}(\bar{x}_{2,1} - \bar{x}_{2,2})^2 + 2C_{12}(\bar{x}_{1,1} - \bar{x}_{1,2})(\bar{x}_{2,1} - \bar{x}_{2,2}) \right) + \frac{S_y^2}{m_1 n_1} \right]^{\frac{1}{2}}$$

where: $S_{y.x}^2$ = residual mean squares

S_y^2 = variance of y prior to adjustment for regression

$\bar{x}_{1,1}$ = mean core specific gravity of trees from which only cores were collected, sample (1)

$\bar{x}_{1,2}$ = mean core specific gravity of trees collected for tree-core relationships, sample (2)

$\bar{x}_{2,1}$ = mean d.b.h./age for sample (1)

$\bar{x}_{2,2}$ = mean d.b.h./age for sample (2)

m_1 = number of trees at each location, sample (1)

m_2 = number of trees at each location, sample (2)

n_1 = number of locations, sample (1)

n_2 = number of locations, sample (2)

(c) The standard error of the core mean was approximated by the following computation when the variances were pooled to obtain the mean core specific gravity of more than one location:

$$\text{standard error} = \sqrt{\frac{K}{(\Sigma n_i)^2}\left(\frac{\Sigma S_i^2 + \bar{x}^2\Sigma n_i^2 - 2\bar{x}\Sigma n_i S_i}{K-1}\right)}$$

where: K = the number of locations at which trees were bored for specific gravity

S_i = the sum of specific gravities of cores at the ith location ($= \Sigma_j X_{ij}$)

(d) When variances were not pooled the standard error of the mean was approximated by--

$$\text{standard error} = \frac{S}{\sqrt{n}}$$

where: S = standard deviation estimated from the sample range of core specific gravities

n = number of observations in sample

8. Percentage difference in specific gravity due to extraction $= \dfrac{\text{unextracted core sp. gr.} - \text{extracted core sp. gr.}}{\text{extracted core sp. gr.}} \times 100$

Table 4.—*Regression equations, correlation coefficients, coefficients of determination, and standard errors for Table-Mountain pine increment core/tree specific gravity relationships*

Regression equations	r	r²	Standard error
Tree specific gravity (Y):			
Y = 0.20620 + 0.62612 (weighted sp. gr., 2 cores) — 0.02143 (total height/age) — 0.03006 (merch. vol./age)	0.82	0.67	0.016
Y = 0.19969 + 0.63456 (weighted sp. gr., 2 cores) — 0.02414 (total height/age)	0.81	0.66	0.016
Y = 0.20267 + 0.58213 (sp. gr., 2 cores) — 0.11624 (merch. vol./age) — 0.00057 (total height)	0.81	0.66	0.016
Y = 0.19970 + 0.62592 (sp. gr., 2 cores) — 0.07867 (merch. vol./age)	0.80	0.64	0.016
Y = 0.22961 + 0.58091 (sp. gr., outer 2/3 of 2 cores) — 0.02533 (total height/age) — 0.01848 (merch. vol./age)	0.80	0.64	0.016
Y = 0.22478 + 0.58797 (sp. gr., outer 2/3 of 2 cores) — 0.02708 (total height/age)	0.80	0.64	0.016
Y = 0.18679 + 0.62006 (weighted sp. gr., 2 cores)	0.80	0.64	0.016
Y = 0.19671 + 0.67628 (weighted sp. gr., 2 extracted cores) — 0.02275 (total height/age)	0.79	0.62	0.017
Y = 0.21092 + 0.65289 (weighted sp. gr., 2 extracted cores) — 0.01875 (total height/age) — 0.03903 (d.b.h./age)	0.79	0.62	0.017
Y = 0.21263 + 0.66448 (sp. gr., 2 extracted cores) — 0.10861 (d.b.h./age)	0.78	0.61	0.017
Y = 0.21400 + 0.64953 (sp. gr., 2 extracted cores) — 0.11724 (d.b.h./age) + 0.00016 (total height)	0.78	0.61	0.017
Y = 0.27057 + 0.51458 (sp. gr., outer 1/3 of 2 cores) — 0.02970 (total height/age) — 0.58989 (1/age)	0.78	0.61	0.017
Y = 0.21368 + 0.63833 (sp. gr., outer 2/3 of 2 extracted cores) — 0.02513 (total height/age)	0.78	0.61	0.017
Y = 0.22057 + 0.62721 (sp. gr., outer 2/3 of 2 extracted cores) — 0.01839 (total height/age) — 0.35694 (1/age)	0.78	0.61	0.017
Y = 0.21150 + 0.56926 (sp. gr., outer 2/3 of 2 cores)	0.78	0.61	0.017
Y = 0.26173 + 0.52717 (sp. gr., outer 1/3 of 2 cores) — 0.04116 (total height/age)	0.77	0.59	0.017
Y = 0.16738 + 0.72398 (sp. gr., 2 extracted cores)	0.77	0.59	0.017
Y = 0.18438 + 0.66216 (weighted sp. gr., 2 extracted cores)	0.77	0.59	0.017
Y = 0.27737 + 0.48229 (weighted sp. gr., 1 core) — 0.13779 (d.b.h./age)	0.76	0.58	0.018
Y = 0.27730 + 0.47951 (weighted sp. gr., 1 core) — 0.15575 (d.b.h./age) + 0.00051 (d.b.h.)	0.76	0.58	0.018
Y = 0.20155 + 0.62053 (sp. gr., outer 2/3 of 2 extracted cores)	0.76	0.58	0.017
Y = 0.19571 + 0.60905 (sp. gr., 2 cores)	0.75	0.56	0.018
Y = 0.29257 + 0.44204 (sp. gr., outer 2/3 of 1 core) — 0.15970 (d.b.h./age) + 0.00090 (d.b.h.)	0.75	0.56	0.018
Y = 0.28940 + 0.45752 (sp. gr., 1 core) + 0.02429 (total height/age) — 0.23618 (d.b.h./age)	0.75	0.56	0.018
Y = 0.29440 + 0.44381 (sp. gr., outer 2/3 of 1 core) — 0.12898 (d.b.h./age)	0.74	0.55	0.018
Y = 0.26223 + 0.54347 (sp. gr., outer 1/3 of 2 extracted cores) — 0.03855 (total height/age)	0.74	0.55	0.018
Y = 0.27038 + 0.53074 (sp. gr., outer 1/3 of 2 extracted cores) — 0.02909 (total height/age) — 0.48389 (1/age)	0.74	0.55	0.018
Y = 0.22792 + 0.53466 (weighted sp. gr., 1 core)	0.73	0.53	0.018
Y = 0.30296 + 0.45436 (sp. gr., 1 core) — 0.18953 (d.b.h./age)	0.73	0.53	0.018
Y = 0.26432 + 0.52483 (sp. gr., 1 extracted core) — 0.14443 (d.b.h./age) + 0.00039 (total height)	0.73	0.53	0.018
Y = 0.27033 + 0.50943 (weighted sp. gr., 1 extracted core) — 0.15972 (d.b.h./age) + 0.00129 (d.b.h.)	0.73	0.53	0.019
Y = 0.28486 + 0.49418 (sp. gr., outer 2/3 of 1 extracted core) — 0.60232 (1/age) — 0.07692 (d.b.h./age)	0.73	0.53	0.019
Y = 0.25139 + 0.47939 (sp. gr., outer 1/3 of 2 cores)	0.72	0.52	0.018
Y = 0.24803 + 0.49295 (sp. gr., outer 2/3 of 1 core)	0.72	0.52	0.018
Y = 0.26783 + 0.54668 (sp. gr., 1 extracted core) — 0.12718 (d.b.h./age)	0.72	0.52	0.019
Y = 0.33221 + 0.39908 (sp. gr., outer 1/3 of 1 core) — 0.05986 (merch. vol./age) — 1.57454 (1/age)	0.72	0.52	0.019
Y = 0.25788 + 0.53010 (sp. gr., outer 2/3 of 1 extracted core) — 0.75174 (1/age)	0.72	0.52	0.019
Y = 0.27549 + 0.50728 (weighted sp. gr., 1 extracted core) — 0.11756 (d.b.h./age)	0.72	0.52	0.019
Y = 0.23604 + 0.54397 (sp. gr., outer 2/3 of 1 extracted core)	0.71	0.50	0.019
Y = 0.21692 + 0.61157 (sp. gr., 1 extracted core)	0.70	0.49	0.019
Y = 0.22824 + 0.56558 (weighted sp. gr., 1 extracted core)	0.70	0.49	0.019
Y = 0.25226 + 0.49746 (sp. gr., outer 1/3 of 2 extracted cores)	0.70	0.49	0.019
Y = 0.30339 + 0.42265 (sp. gr., outer 1/3 of 1 core) — 1.18958 (1/age)	0.70	0.49	0.019
Y = 0.24380 + 0.50900 (sp. gr., 1 core)	0.69	0.48	0.019
Y = 0.34629 + 0.35131 (sp. gr., outer 1/3 of 1 extracted core) — 0.24552 (d.b.h./age) + 0.00198 (d.b.h.)	0.66	0.44	0.020
Y = 0.27919 + 0.42233 (sp. gr., outer 1/3 of 1 core)	0.66	0.44	0.020
Y = 0.36148 + 0.33462 (sp. gr., outer 1/3 of 1 extracted core) — 0.18543 (d.b.h./age)	0.64	0.41	0.021
Y = 0.30008 + 0.39595 (sp. gr., outer 1/3 of 1 extracted core)	0.59	0.35	0.022

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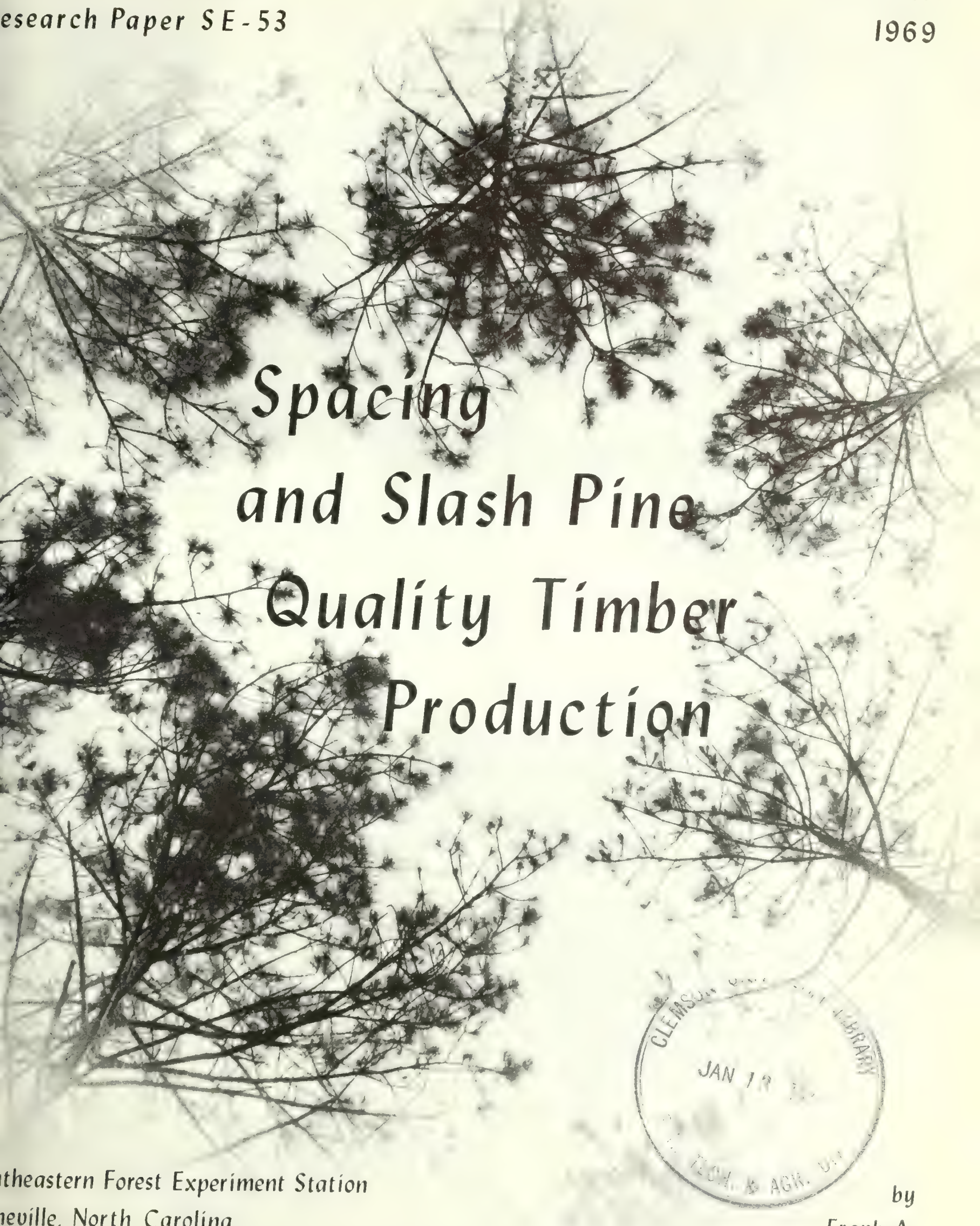

Spacing and Slash Pine Quality Timber Production

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by
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SPACING AND SLASH PINE QUALITY TIMBER PRODUCTION

by

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Cubic volume production as related to spacing in planted slash pine *(Pinus elliottii* var. *elliottii)* is well understood. Yield increases as number of surviving trees per acre increases, although at a diminishing rate after a certain point. It is also well known that wider spacings, 200 to 400 trees per acre, are necessary for optimum sawtimber yields at 25 to 30 years of age. However, many foresters question the value of open spacings for sawtimber and veneer stock production because of the wide annual rings and the lack of self-pruning. They believe a narrow spacing is necessary to produce lumber that meets the "dense" classification. Southern Pine Inspection Bureau (SPIB) (1968) specifies that dense lumber "averages on either one end or the other not less than 6 annual rings per inch and not less than 1/3 summerwood, ... Pieces averaging less than 6 annual rings per inch and not less than 4 meet dense requirements if averaging 1/2 or more summerwood."

No published report compares dense lumber production with spacing of planted slash pine. This paper makes such a comparison through the use of data from a slash pine spacing study on the George Walton Experimental Forest, Dooly County, Georgia.

THE STUDY

Eight spacings, replicated twice, were established in January 1952 in a field which had been cultivated the previous year. Beginning in 1952, heights have been measured annually; starting in 1955, at the end of the fourth growing season, diameter at breast height (d.b.h.) has been measured annually for each spacing on the interior half of 3/4-acre plots (table 1). Details of growth and development through age 12 have been reported by Harms and Collins (1965).

Rings per Inch

For grading purposes, number of rings per inch can be established by diagraming the mean diameters in table 1 (fig. 1). These diagrams illustrate that even the 6 by 6 spacing produces a tree with a wide-ringed core. Eliminating this wide-ringed core would require an extremely close spacing, with precommercial thinning at an early age to avoid the adverse effects of stand density on diameter and height growth (Collins 1967).

The innermost growth ring in the diagrams of figure 1 represents the mean diameter at age 4. Because all the spacings averaged about 3 feet in height at age 2 and about 6 feet at age 3, there is an annual ring (not indicated) in this core which represents only a portion of a year's growth. For example, half the third year's height growth was spent in reaching the 4.5 foot-level, so only a portion of a year's diameter growth could be put on at that level.

Table 1.—Inside-bark diameters at various ages[1]

Age (years)	Spacing (feet)							
	6 by 6	6 by 8	5 by 10	8 by 8	6 by 12	10 by 10	7-1/2 by 15	15 by 15
	Inches							
4	0.83	0.74	0.73	0.67	0.75	0.95	0.86	0.88
5	1.69	1.91	1.90	1.78	1.89	2.12	2.02	2.20
6	2.15	2.51	2.48	2.62	2.71	2.95	2.83	3.04
7	2.53	3.04	3.09	3.14	3.17	3.50	3.48	3.74
8	2.89	3.38	3.27	3.50	3.61	3.97	4.00	4.36
9	3.16	3.68	3.51	3.81	3.99	4.39	4.42	4.95
10	3.33	3.89	3.73	4.10	4.28	4.78	4.79	5.47
11	3.48	4.06	3.88	4.37	4.51	5.14	5.05	5.94
12	3.62	4.26	4.11	4.56	4.77	5.39	5.41	6.35
13	3.70	4.42	4.26	4.72	4.92	5.60	5.62	6.73
14	3.89	4.66	4.44	4.92	5.10	5.85	5.87	7.10
15	3.96	4.69	4.54	5.03	5.23	6.02	6.03	7.35

[1] Inside bark diameters were determined by deducting double bark thickness = 0.467 + 0.107857 (d.b.h.).

When the annual diameter-growth rate of any tree is permanently reduced to 0.33 inch or lower, all wood produced thereafter will qualify as dense on the basis of the most restrictive ring count per inch. SPIB (1968) specifications for determining ring count read as follows:

> Average annual rings per inch and percentages of summerwood as required in Dense and Longleaf shall be determined by measurement over the specified portion of a radial line extending from the pith. (a) In pieces that contain the pith, the measurement shall be over the third, fourth and fifth inches from the pith if the radial line is 5-inches long or more; over the third and fourth inches from the pith if the radial line is less than 5-inches long and not less than 4″; over the third inch from the pith if the radial line is less than 4-inches long and not less than 3″; and over the farthest inch from the pith if the radial line is less than 3-inches long. (b) In pieces that do not contain the pith, the radial line shall start at the point on the edge nearest the pith and the measurement shall be over the three-inch portion of the radial line farthest from the pith if the radial line is 5″ long or more; over the two-inch portion farthest from the pith if the radial line is less than 5-inches long and not less than 4″; over the one-inch portion farthest from the pith if the radial line is less than 4-inches long and not less than 3″; and over the farthest inch from the pith if the radial line is less than 3-inches long. (c) The measurement shall be made over a 1/2-inch portion of the radial line in any case where a 1-inch portion is not available.

For a timber containing the pith and at least a 3-inch radial line, width of annual rings within the 4-inch core is of no particular importance. The width of these rings might be important either when the timber does not contain the pith or when radial lines are less than 3 inches or both.

All spacings except the 15 by 15 have reached the 0.33-inch growth level by age 13 (table 2); in fact, the four closest spacings are at this point by age 9. These growth rates were established by subtracting the mean diameter at each age from the mean diameter the next year. Fluctuations in growth rate within a spacing can be primarily attributed to year effect.

Since the growth rate after age 13 of the 7-1/2 by 15 spacing meets dense requirement for number of rings per inch, we can assume any mean d.b.h. (such as 12 inches) and evaluate the production of dense material for the average tree of this spacing (fig. 2). Dimension material and/or timbers that qualify as dense on the basis of ring count per inch at d.b.h. can be sawed from a tree this age and size. Either a 4x10, a 6x10, a 6x8, a 4x1, a 6x6, or a 4x4 timber, plus several 2-inch dimension pieces with each, that would meet the 6-rings-per-inch specification, could be sawed from this tree; or one

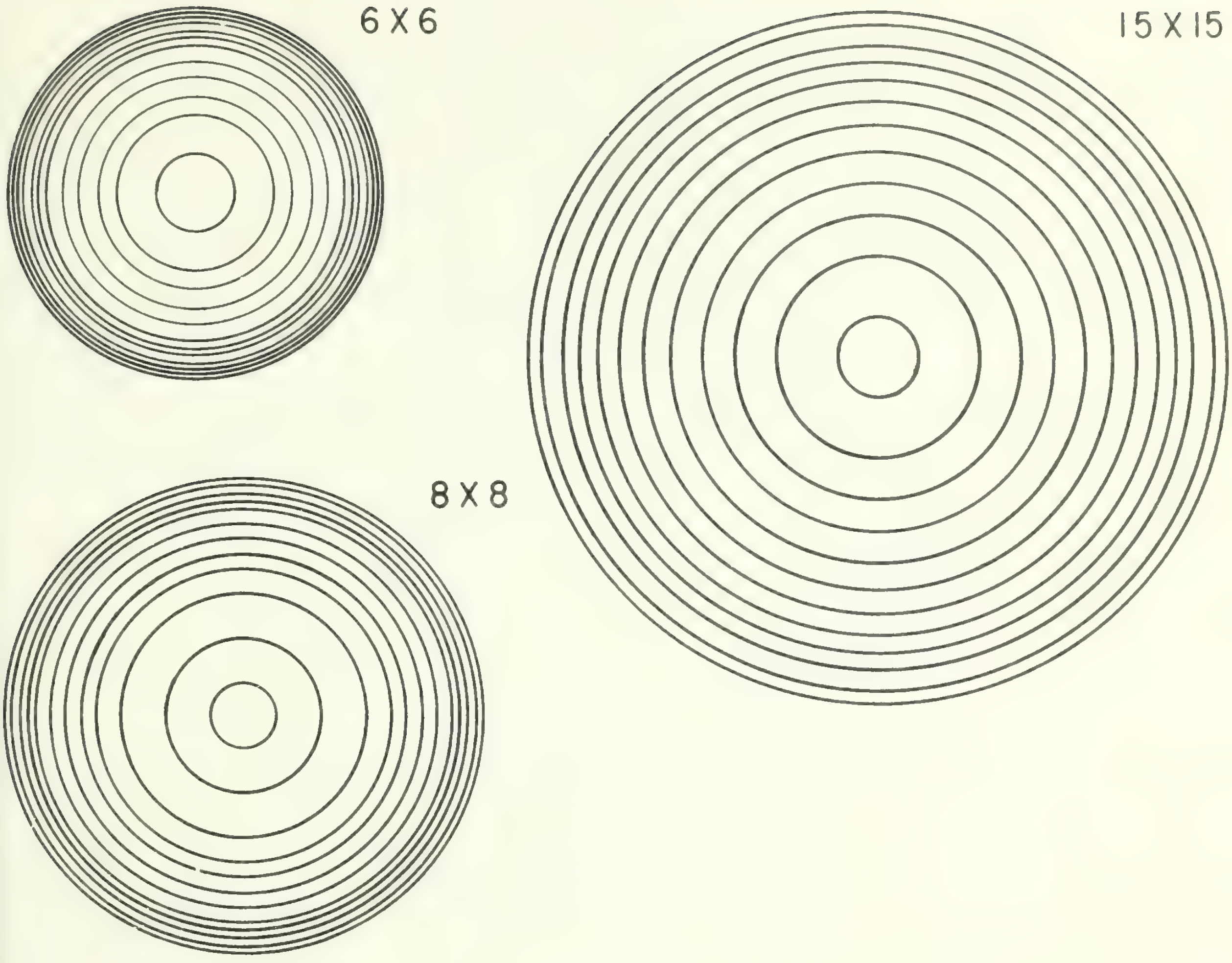

Figure 1.—Growth patterns, through age 15, for the average tree of the 6 by 6, 8 by 8, and 15 by 15 spacings. Scale 1/2:1 inch.

Table 2.—Annual diameter growth rates (inside bark) by spacing[1]

Age (years)	Spacing (feet)							
	6 by 6	6 by 8	5 by 10	8 by 8	6 by 12	10 by 10	7-1/2 by 15	15 by 15
	Inches							
5	0.86	1.17	1.17	1.11	1.14	1.17	1.16	1.32
6	0.46	0.60	0.58	0.84	0.82	0.83	0.81	0.84
7	0.38	0.53	0.61	0.52	0.46	0.55	0.65	0.70
8	0.36	0.34	0.18	0.36	0.44	0.47	0.52	0.62
9	0.27	0.30	0.24	0.31	0.38	0.42	0.42	0.59
10	0.17	0.21	0.22	0.29	0.29	0.39	0.37	0.52
11	0.15	0.17	0.15	0.27	0.23	0.36	0.26	0.47
12	0.14	0.20	0.23	0.19	0.26	0.25	0.36	0.41
13	0.08	0.16	0.15	0.16	0.15	0.21	0.21	0.38
14	0.19	0.24	0.18	0.20	0.18	0.25	0.25	0.37
15	0.07	0.03	0.10	0.11	0.13	0.17	0.15	0.25

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[1] Growth rates below the dashed line will average 4 rings per inch; growth rates below the solid line will average 6 rings per inch.

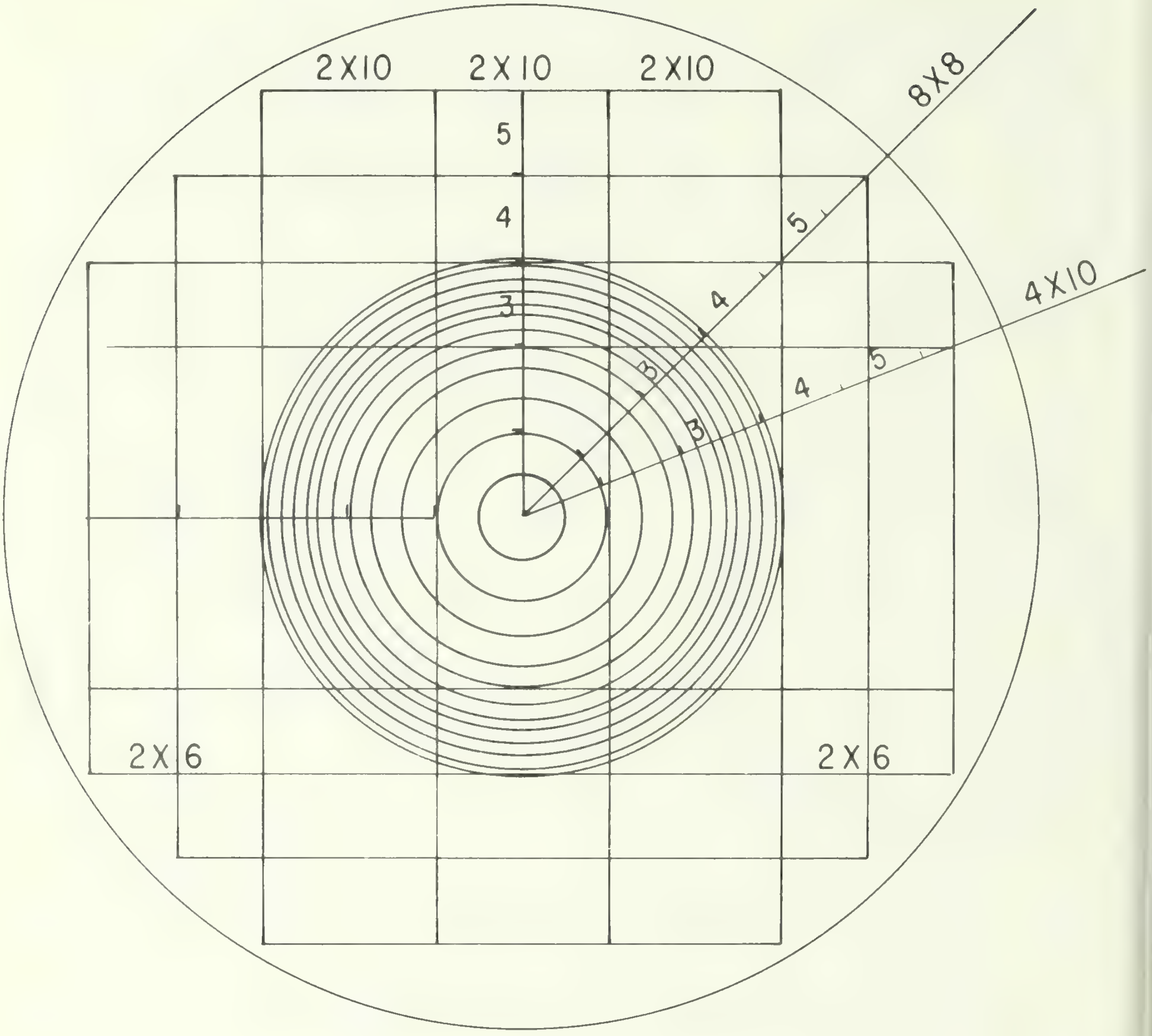

Figure 2.—Trees in the mean diameter class of the 7-1/2 by 15 spacing (360 surviving trees per acre) produce timber that will qualify as dense, on the basis of 6 rings per inch at d.b.h. The check (√) indicates where the ring count should be made on dimension timbers not containing the pith. Scale 1/2:1 inch.

8x8 timber meeting dense requirements could be produced. If only 2-inch dimension material were desired, sawing would yield three 2x10 and two 2x6 pieces, all meeting the dense requirement of 6 rings per inch.

From a sawtimber standpoint, the primary interest will not be the average tree but the 100 to 150 best and largest trees. Figure 3, a diagram of the growth pattern of the first diameter class above the average or mean class, shows that all timbers and most of the 2-inch dimension stock will meet the 6-rings-per-inch specification. A similar diagram of the growth pattern of trees in the second class above the mean class indicates these trees will not average 6 rings per inch at the appropriate measurement points.

However, SPIB stipulates that lumber with 4 rings per inch qualifies as dense if it averages at least 50 percent summerwood.

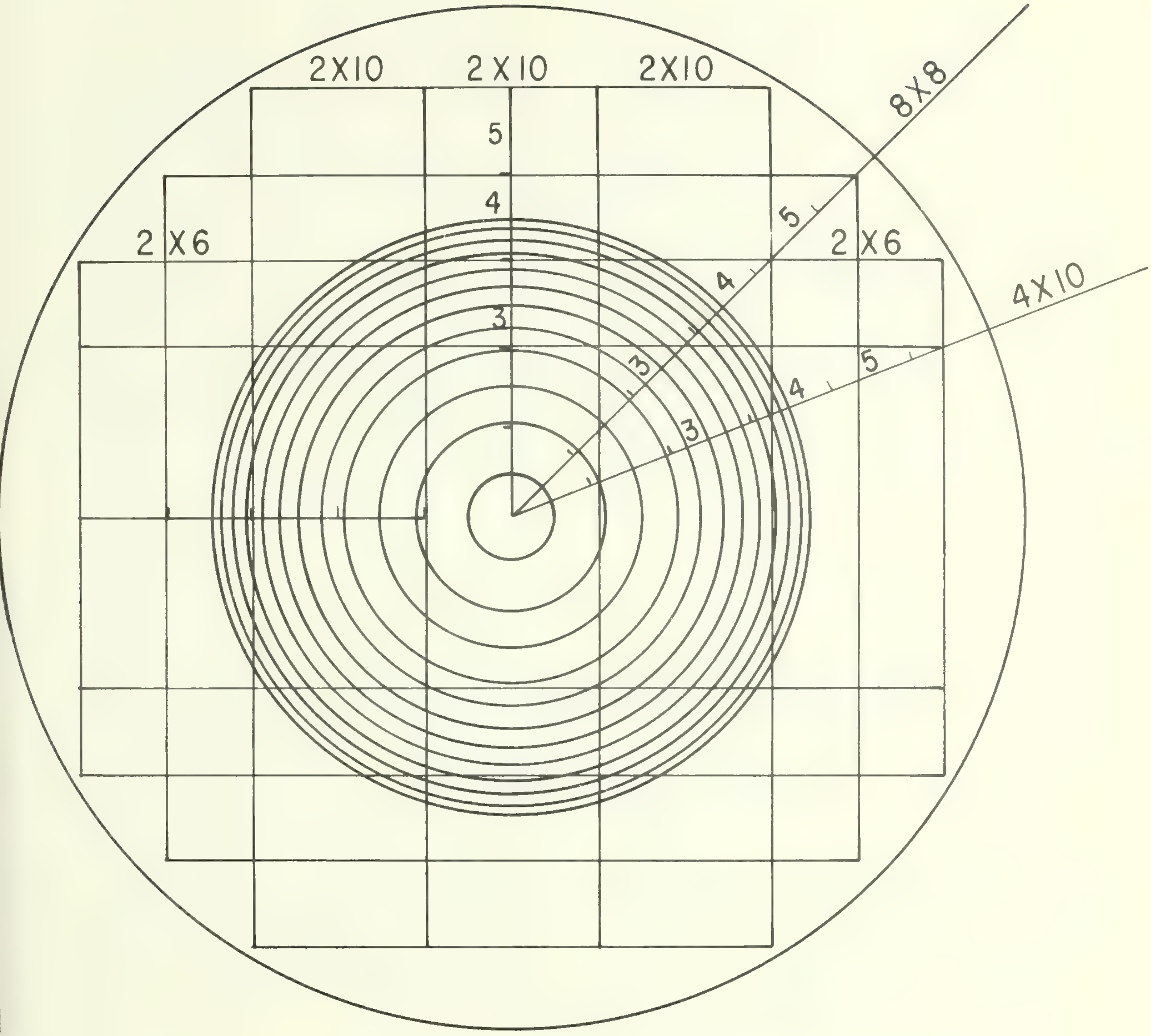

Figure 3.—Growth pattern of the first diameter class above the mean class in the 7-1/2 by 15 spacing. Scale 1/2:1 inch.

Larson (1957) reports that natural slash pine will average 50 percent summerwood by age 10, with a steady increase to 60 percent by age 21. Although Larson's increment core samples were taken at 3.5 feet above ground, a number of studies have reported a high degree of correlation between average wood properties at d.b.h. and averages for the entire tree (Mitchell and Wheeler 1959; U.S. Forest Service 1965).

There is little doubt that, in the 7-1/2 by 15 spacing, the 360 trees per acre surviving at age 15 will average 4 rings per inch at the appropriate measurement points. Diagrams of growth patterns of trees in the 15 by 15 spacing (180 survivors per acre at age 15) show that trees in the mean diameter class and below will meet the 4-rings-per-inch requirement (fig. 4). Diagrams of the growth patterns of larger trees indicate some dense material can be expected from the first diameter class above the mean, but none can be expected from any larger class.

According to the National Bureau of Standards, U.S. Department of Commerce,

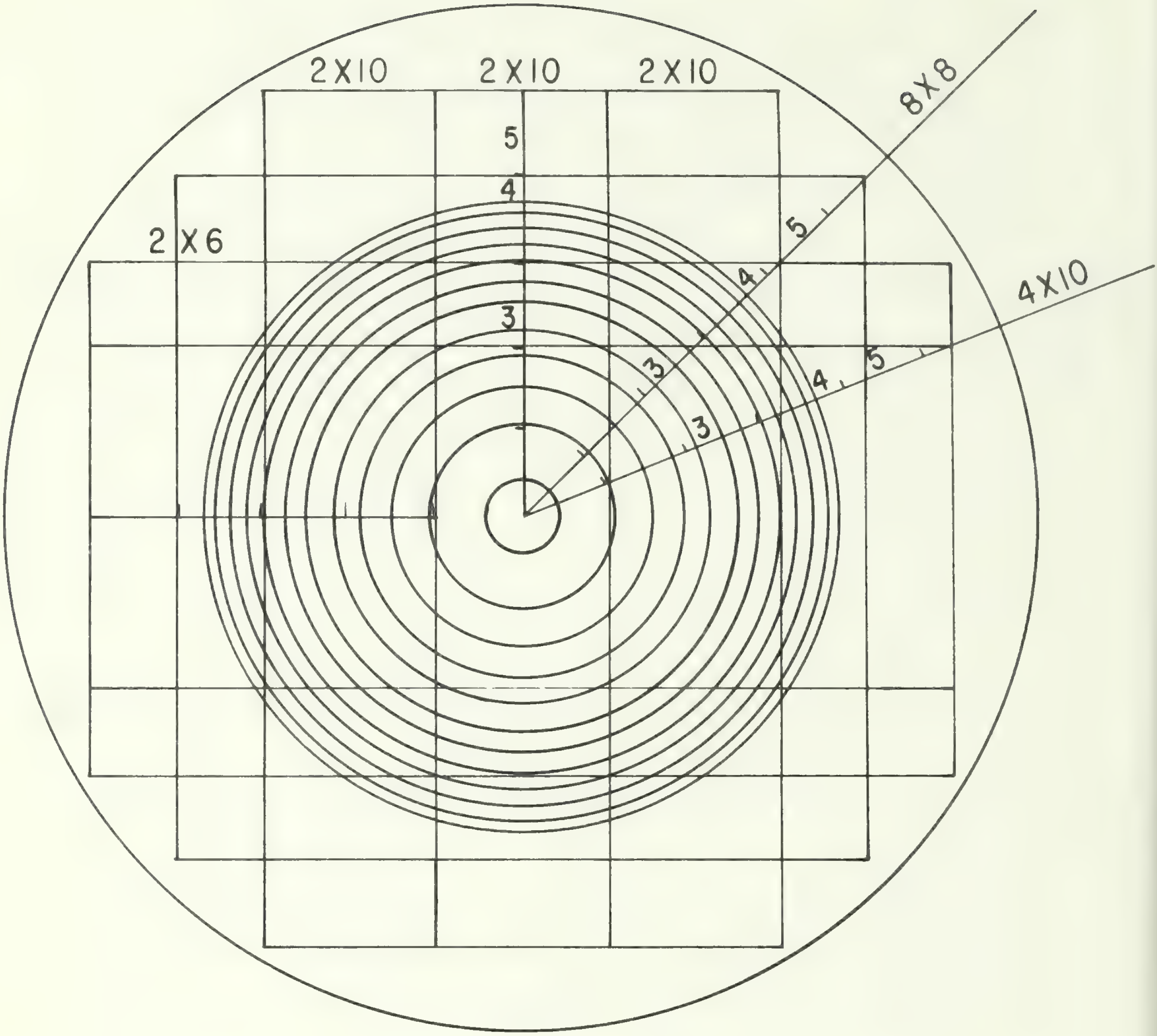

Figure 4.—Growth pattern of the mean diameter class for the 15 by 15 spacing. Scale 1/2:1 inch.

CS-259-63, any log that will produce "dense" dimension lumber and timber will also qualify as veneer stock. Discarded veneer cores average 4 to 5 inches in diameter so the wide-ringed core is no particular problem.

Although the ring counts established relate to measurements at d.b.h., the grading rules specify that ring count can be made at either end of a timber. Inspection of two trees selected at random from two plantations, 28 and 30 years of age, showed the ring pattern at 17 feet to be about the same as at d.b.h. Comparing the total number of rings at 17 feet with the same number of rings at d.b.h., counting from the pith, shows the diameters are similar:

Spacing	Number of annual rings	D.b.h.	17 feet
		Inches	
15 by 15	23	9.92	10.08
8 by 8	25	7.44	7.20

The difference in total diameter at d.b.h. and 17 feet can be primarily attributed to the difference in age at the two points.

Summerwood Percentage and Wood Density

Because summerwood percentage is highly important in quality timber production, a logical question is whether this characteristic is affected by spacing. The evidence seems preponderant that spacing has little effect on either summerwood percentage or specific gravity.

Larson (1957) found growth rate exerted a negligible influence on both summerwood percentage and specific gravity of natural slash pine. Data filed at the Southeastern Forest Experiment Station show percentage summerwood to have little correlation with stand density. This unpublished study was designed specifically to evaluate the effect of age, site, and spacing on the growth and yield of planted slash pine. Zobel et al. (1965), reporting on a localized study in South Carolina, found wood density of loblolly pine to be practically independent of stand density.

Banks and Schwegmann (1957) found the same lack of significant correlation between growth rate and wood density in both *Pinus taeda* and *Pinus patula* grown in South Africa. These researchers found the aggregate density of fast-grown material ". . . as great and sometimes greater than that for slow-grown trees owing to the larger percentage of dense wood formed by the former towards the end of the rotation." They further reported ". . . that the radial, tangential, longitudinal, and volumetric shrinkage is virtually the same for both slow- and fast-grown timber." And, Jayne (1958) found spacing to have only a minor effect on the specific gravity of red pine.

Production of Clear Material

Stand density does directly influence the production of *clear* material. Close spacings cause early self-pruning; wide spacings result in large knotty cores and produce little clear material at 25 and 30 years of age.

Since spacing has little influence on the production of dense lumber, the forest manager can use a wide spacing and artificial pruning to produce clear lumber and veneer stock, or a narrow spacing that will induce self-pruning. Which method is better? Data filed at the Naval Stores and Timber Production Laboratory, Olustee, Florida, show that 800 trees on site 70 (25-year basis) at age 11 will appear as follows:

Diameter class	Number of trees[1]	Height	Crown ratio percent	Height of live crown above ground
		Feet		*Feet*
2	19	. .	....	.
3	130	.	. .	. .
4	244	34	48	17.7
5	243	37	51	18.1
6	135	39	54	17.9
7	29	40	57	17.2

[1] A comprehensive publication covering this, and many other aspects, is being prepared.

According to Paul (1938), dead limbs and stubs of slash pine are not shed for about 6 years, so the site 70 stand would be 17 years or older before clear material could be laid down on the butt log. At age 17 the distribution of this stand would be as follows:

Diameter class	Number of trees
2	5
3	39
4	102
5	162
6	189
7	167
8	104
9	32
10	1

The largest trees are 7, 8, and 9 inches in diameter. Despite heavy stocking, the knotty core on what should be the final crop trees will not be small; and the high stand density will severely limit saw-log and veneer production. Eighteen percent of the stand at age 17 is nonmerchantable for pulpwood.

Paul further points out that small branches of southern pine often persist longer after dying than larger ones. Branches less than ½ inch in diameter have been known to persist for almost 50 years.

The three dense structural grades, as defined by the SPIB rules, permit knots of varying sizes (table 3). For example, when the widest face on timbers and dimension stock is 10 inches, knots are permitted to range from 3/4 inch in Dense Structural 86 to 2-3/4 inches in Dense Structural 65. As face width increases, permissible knot size increases.

Paul (1938) reports average knot size to be 1/2 inch in the first 20 feet of the stem

Table 3.—A partial listing of knot sizes permitted by SPIB in the three dense structural lumber grades

Nominal width	Knot size at the edge of wide face			Knot size on the narrow face[1]		
of face	Structural grade			Structural grade		
(inches)	86	72	65	86	72	65
	Inches					
4	5/16	5/8	13/16	1/2	1-1/8	1-3/8
5	3/8	3/4	1	5/8	1-3/8	1-3/4
6	7/16	15/16	1-1/8	3/4	1-5/8	2
8	5/8	1-1/4	1-1/2	1	2	2-1/2
10	3/4	1-1/2	2	1-1/8	2-1/4	2-3/4
12	7/8	1-7/8	2-3/8	1-1/4	2-3/8	3
14	1	2	2-1/2	1-5/16	5/8	1/4

[1] Permissible knot size in the center of the face is just about double that permitted at the edge of the wide face.

in natural slash pine stands ranging from 330 to 460 trees per acre. Only 5 percent of the knots were more than 1 inch in diameter. Knot sizes in stands planted at similar stocking will probably be somewhat larger because heavier initial stocking in the natural stand suppresses knot size. It appears that knot size in planted stands of 300 or more trees per acre will not be a limiting factor in the larger timbers, except for structural grade 86. Grades 72 and 65 generally permit knots up to 2-3/4 inches in large dimension stock.

Considering the limiting effect of close spacing on tree size and board-foot production, artificial pruning is an appealing alternative. If total sawtimber or veneer stock yield is compared at a given age, such as 30 years, producing clear material through use of wide spacing and artificial pruning will be cheaper than using close spacing and natural pruning. Records show, for example, a surviving stand of 200 planted slash pine per acre on site 70 produces about 7,300 board feet at age 25; a stand of 800 trees produces about 24 percent as much.

The author has shown that the knotty core can be held to 5 or 6 inches through the use of two-phase pruning (Bennett 1956). This is about 3 inches smaller than the knotty core expected from the 136 largest trees in an 800-tree stand. The difference in net return between butt logs with 5-inch and 7-inch knotty cores, from the study just cited, was 69 cents based on a premium of $30 per thousand for clear boards. The total cost of pruning, which was by hand, averaged about 10 cents per tree. Although the same type of pruning would cost more today, mechanical pruners are being developed to permit limbing to any height.

SUMMARY AND CONCLUSIONS

Spacing apparently does not profoundly affect the production of dimension lumber and timbers that meet SPIB's "dense" classification. Neither does spacing affect summerwood percentage or specific gravity in the production of quality timber. Thus, there is little point in maintaining heavy stands for the production of dense material. Although close spacings induce early self-pruning, up to age 25 or 30 a wide spacing (200 to 400 trees per acre) and artificial pruning will result in much more clear volume than a narrow spacing and self-pruning. Also, since only planting at 200 to 400 trees per acre will produce acceptable quantities at age 25 to 30, these wider spacings should be employed, if artificial pruning is possible, when the primary production goal is sawtimber and veneer stock.

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BY

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ORIGIN AND DEVELOPMENT OF EPICORMIC BRANCHES IN SWEETGUM

by

Paul P. Kormanik and Claud L. Brown

Epicormic branches account for a high percentage of defects in many commercially important forest trees. European foresters have been concerned with epicormic branches in forest management since the late 18th and early 19th centuries. American foresters first became cognizant of the problem in the early 1900's as virgin hardwood stands diminished and second-growth stands became the primary source of hardwood lumber.

Several recent papers point out the high incidence of epicormic branches. Hedlund (1964), in surveying a nine-county area in the North Louisiana Delta, found that epicormic branches occurred on the second log of 72 percent of the sawlog-size hardwoods. These branches caused degrade in 40 percent of the sample logs; of these, 23 percent were lowered two or more grades. Earlier, Bryan (1960) studied 29 factors causing log degrade in Southern Piedmont hardwoods. Eight of these he traced directly to the development of epicormic branches which reduced the quality on 54 percent of the log sections.

Primary defects are not the only problem associated with the occurrence of epicormic branches. Such branches are usually short lived, and when they die their scars or stubs serve as places of entry for diseases and insects that cause more serious secondary defects. Büsgen and Münch (1929) found that epicormic branches on beech were more readily attacked by canker fungi than were ordinary shoots, and that infection by diseases hastened the death of these branches in some species.

Many observations have been made on the origin of epicormic branches, principally by horticulturists working with fruit trees (Hahne 1926; Chandler 1925, 1947). In these studies, primary emphasis has been placed on the axillary buds of lateral branches because they may be ultimately involved in fruit production. Studies of growth and development of buds on the boles of timber species have been less numerous. The need for such information is now apparent because more intensive hardwood management and the use of improved strains will result in a larger proportion of future stands grown in plantations. The intensive silvicultural practices associated with plantation management are also those most favorable for the eruption of epicormic branches (Clark 1955; Berntsen 1961).

Wilcox (1963) pointed out that resistance to epicormic branching is receiving major attention in hardwood breeding and selection programs throughout the South. A thorough knowledge of bud formation and development and how buds become suppressed in different species will aid in making meaningful genetic selections for freedom from epicormic branching.

The buds from which epicormic branches arise may originate in several ways. One mode of origin is from accessory buds formed at nodes on the current year's shoots. As such, they may originate in the scale axils of the axillary bud (Stone and Stone 1943); from meristematic tissue in the leaf axil adjacent to the axillary bud (Tucker 1963); or from the axillary bud itself. In addition, adventitious buds[1] in some species may also give rise to epicormic branches. Buds which originate on the current year's shoot as accessory buds, like the axillary buds, are characterized by vascular traces extending to the pith. In distinct contrast, the vascular traces of adventitious buds do not extend to the pith, but connect with the existing primary or secondary xylem near their point

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[1] Buds arising any place outside the normal phyllotaxy from various tissue, in an unpredictable pattern.

of origin. During subsequent growth and development of the main axis, these preformed buds may become embedded in the periderm and may later branch repeatedly in some species, thus giving rise to numerous secondary buds. This has been described by Chandler (1925, 1947), Hahne (1926), Büsgen and Münch (1929), Kramer and Kozlowski (1960), and Kormanik and Brown (1964).

The terminology used in describing buds which give rise to epicormic branches is somewhat misleading and needs clarifying. For example, such buds are referred to by different workers as "adventitious buds," "dormant buds," "dormant trace buds," "trace buds," "inhibited buds," "suppressed buds," "preventitious buds," or even "bud-forming tissue." The word dormant has many connotations, viz summer dormancy or quiescence versus winter dormancy or rest. Buds embedded in the periderm are at times quite active. For these reasons we think the terms "inhibited buds" and "suppressed buds" better describe physiological conditions throughout the year. In the remainder of this paper we will use "inhibited buds" to mean the inhibition of axillary and accessory buds on the current year's twigs by an actively growing apex, and also, to mean all other visible buds on different age shoots which remain completely inhibited. Likewise, the term "suppressed bud" will be used to specify those buds embedded in the periderm which are inhibited to varying degrees. Thus, by our definition, epicormic branches will always arise from suppressed buds whose traces may extend to the pith if they arose from axillary or accessory buds, or back to some other tissue if they arose as adventitious buds and later became embedded in the periderm.

The purpose of this investigation was to describe the morphological development of epicormic branches in sweetgum *(Liquidambar styraciflua* L.) and to study some of the physiological factors involved in this development.

METHODS

The origin and development of suppressed buds in sweetgum were traced on seedlings, on stump sprouts, and older trees. The specific methods will be discussed in individual sections of the paper.

The specimens used for histological studies were killed in formalin-acetic acid-alcohol (FAA), dehydrated in a tertiary-butyl alcohol (TBA) series, embedded in Tissuemat, and sectioned on a rotary microtome at 10-12 μ. The sections were stained with Northen's variation of Foster's tannic acid-iron chloride method (Johansen 1940). Material was collected from Clarke, Oconee, and Greene counties, Georgia, so to provide genetic diversity.

We also observed bud development on the current year's shoots of sweetgum in several locations (Virginia, North Carolina, Kentucky, Indiana, Ohio, and Tennessee) within the natural range of the species, and found the pattern to be the same as that observed in the study area.

MORPHOLOGICAL AND ANATOMICAL OBSERVATIONS OF BUD DEVELOPMENT

The following observations were made to describe the seasonal pattern of bud formation and shoot extension in young and mature trees. Such descriptive work was essential to determine which buds normally develop into lateral branches during the current season's growth, which ones might possibly abort during this period, and, of primary interest, which ones remain inhibited long enough to become embedded in the periderm to persist as suppressed buds.

Bud and Branch Development—First Year

Terminal buds were collected in late February and early March before new shoot growth started. At this stage, the immature leaves, along with their axillary bud primordia, are visible (fig 1). No attempt was made to distinguish the apical meristem initials of collateral buds[2] subjacent to the axillary buds. Although we did not study the ontogeny of these initials, we believe they are present when the terminal buds begin to swell.

Shoot growth of sweetgum usually begins in the Athens, Georgia, area around the first of April, and it is characterized by slight internodal elongation and unfolding of the leaf primordia at each node. Adnate stipules are present at the base of the petiole of each leaf and these remain conspicuous during most of the growing season. Axillary buds have not matured when the first basal leaves begin growth and, at this stage, they consist of an apical

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[2] Arrangement of accessory buds on either side of the axillary bud (Harlow and Harrar 1950).

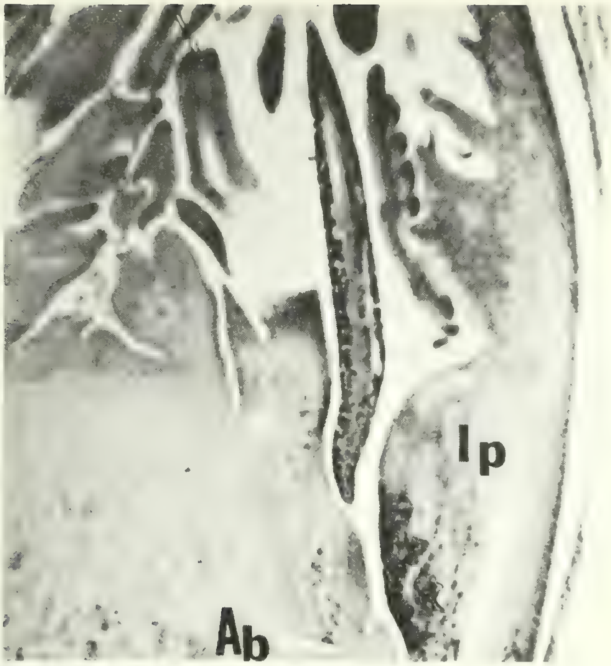

Figure 1.—Longisection of dormant terminal bud showing leaf primordia (lp) and axillary buds (A_b), X128.

meristem covered by two small scales. Collateral bud initials are readily distinguished at this stage in the axils of these two scales (fig. 2).

As the terminal bud begins to elongate, first-formed leaves at the base of the shoot remain relatively small, and the axillary buds that develop at the basal four to five nodes of the current year's shoot differentiate and mature but do not grow into lateral branches. During the current year these axillary buds normally remain small and inconspicuous, often less than a millimeter in diameter. The collateral bud initials become prominent in these basal buds within 4 weeks after growth starts in the spring (fig. 3).

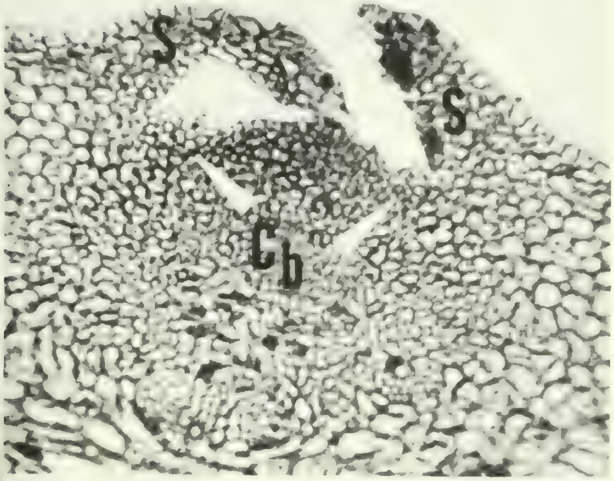

Figure 2.—Transverse section of basal axillary bud showing apical initials of the collateral buds (C_b), and the scales (S) subtending them, X560.

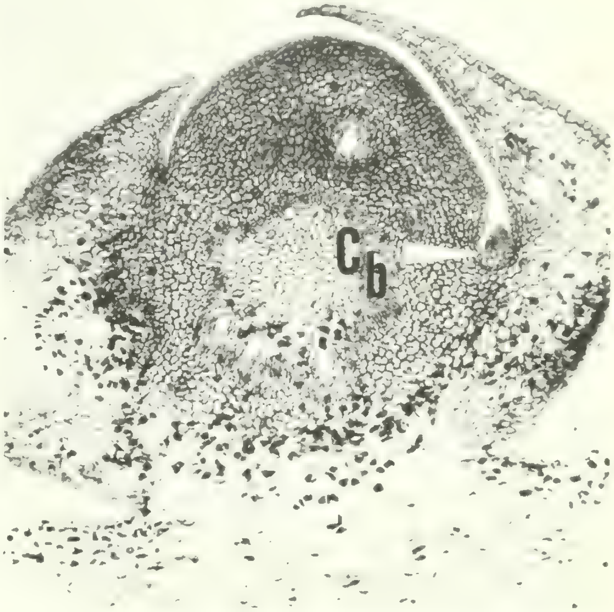

Figure 3.—Longisection of basal axillary bud in a later stage of development (early summer) showing well-developed collateral buds (C_b) in axils of the bud scale, X200.

The axillary buds in the next-formed three to five nodes mature quickly and begin to swell before the first leaf is mature. These same axillary buds in sweetgum usually develop into lateral branches about 3 to 4 weeks later. During this latter period of development, the basal two scales of the axillary bud which cover the collateral buds become quite distinct and are characteristic of sweetgum axillary buds in young stems (fig. 4).

As extension growth proceeds acropetally, newly formed axillary buds develop so rapidly that almost all of them proximal to the shoot apex elongate into lateral branches as soon as they are formed. The growth of these uppermost axillary buds into lateral branches begins long before their subtending leaves mature, and apparently the two basal scales are the only ones initially produced by the rapidly developing bud. Two interesting features of these nodes are: (1) the collateral buds are quite distinct and well formed almost as soon as extension growth of axillary buds begins, and (2) the

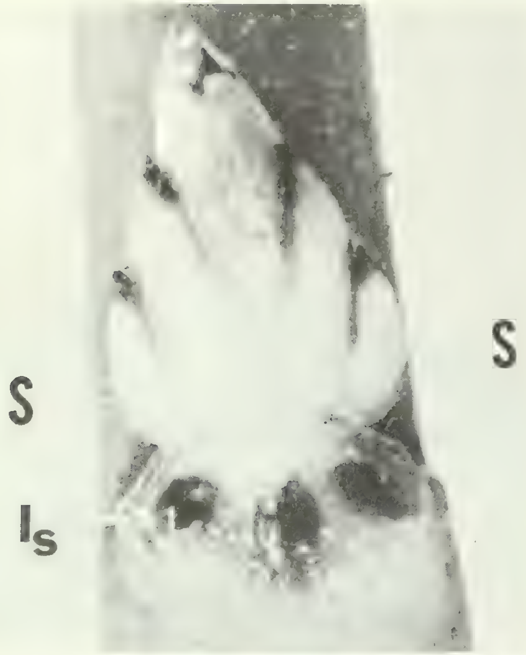

Figure 4.—Axillary bud with the two distinct basal scales (S) covering well-developed collateral buds, and scar of detached leaf (l_s), X2.

two scales subtending these buds do not degenerate rapidly but undergo considerable secondary elongation (fig. 5).

In contrast to the bud scale development prevailing within the uppermost axillary buds, the basal scales on those near the middle portion of the extended shoot (cf. fig. 4) remain small and the collateral buds develop in their axils. When the axillary buds along this region of the shoot begin growing into lateral branches toward the end of May, the collateral buds are mature (fig. 6).

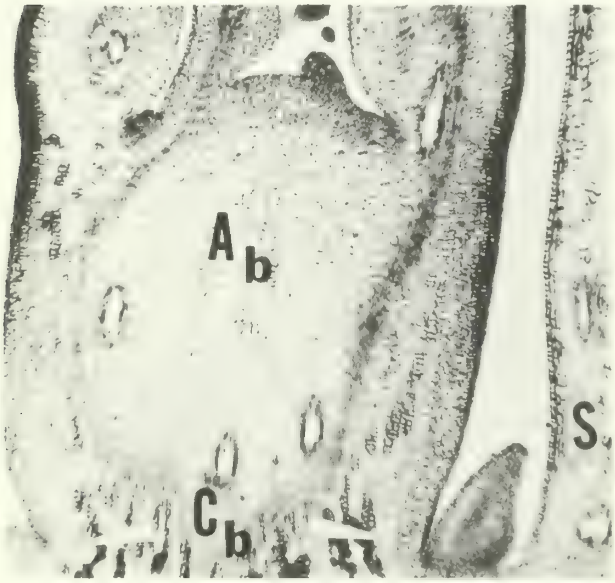

Figure 5.—Longisection of axillary bud (A_b) in early stages of elongation showing well-developed collateral buds (C_b) and elongated bud scales (S).

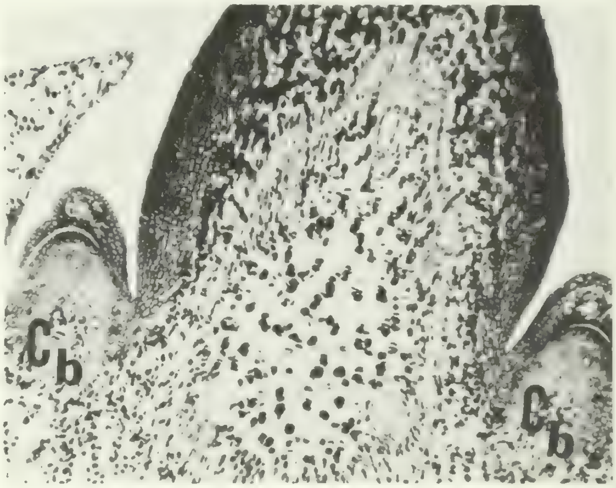

Figure 6.—Longisection of axillary bud with mature collateral buds (C_b) in the scale axils.

The distinct growth characteristics of all axillary buds in the uppermost nodes continue during the remainder of the growing season. In fact, in most cases the second or third axillary bud just below the apex of the elongating shoot begins to extend before elongation has ceased in the internode above. Rapid stem elongation and axillary bud growth continue throughout June and into the middle of July. Toward the latter part of July and early August, growth rapidly declines. The last few axillary buds that develop before growth ceases do not elongate, but the two basal scales are prominent and histological observations reveal well-formed collateral buds in their axils.

The last-formed, uppermost axillary buds differ considerably in size and appearance from those produced earlier. On stems with low vigor they consist of the two enlarged basal scales covering the immature axillary bud (fig. 7). In this respect they resemble the axillary buds characteristic of the basal four or five nodes. On normal or vigorous stems these last-formed axillary buds are much larger and have numerous scales, and the basal two scales which subtend the collateral buds are small but distinct (fig. 8, page 6).

Thus, the terminal leader of sweetgum exhibits several distinctive features after growth ceases for the current year. The distal axillary

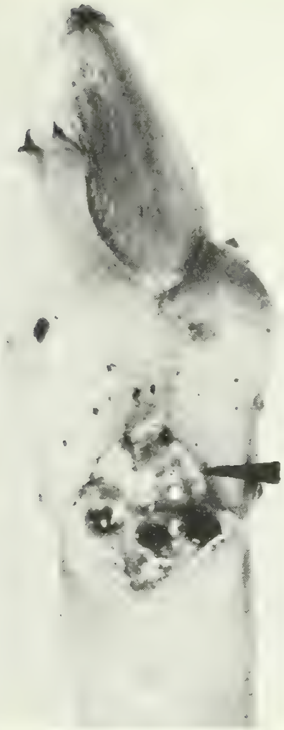

Figure 7.—Arrow points to one of the last-formed axillary buds on a low-vigor shoot; there are only two bud scales.

buds retain their collateral buds in the axils of their basal two scales (fig. 8, B). The collateral buds associated with the elongated lateral branches (fig. 8, C) and the basal axillary and their collateral buds (fig. 8, D) are usually inhibited in growth during the current year.

Bud and Branch Development — Second Year

The growth of axillary buds and lateral branches on second year stems varies considerably. A few axillary buds in the basal nodes break dormancy and begin to develop into branches early in the spring of the second year, but some do not break dormancy until late in the summer, or even until the beginning of the third growing season. As a general rule, all the buds beginning growth early in the spring develop into low-vigor branches. The collateral buds at the base of these branches, although well developed and distinct, remain inhibited. Those basal buds breaking dormancy later in the summer, or during the third year, develop into lateral branches of even lower vigor. They normally die during the year they are initiated. The collateral buds associated with these lateral branches of low vigor remain rather inconspicuous and frequently become embedded before the branches die (fig. 9).

Terminally positioned axillary buds characteristically develop into ephemeral branches during the second year (fig. 10, A, page 7). Most of these short-lived branches function throughout the second year and some even during the succeeding year, but few survive beyond the third year. Collateral buds associated with this type of branching are, as a general rule, barely visible on the bark surface by the end of the second year (fig. 10, B).

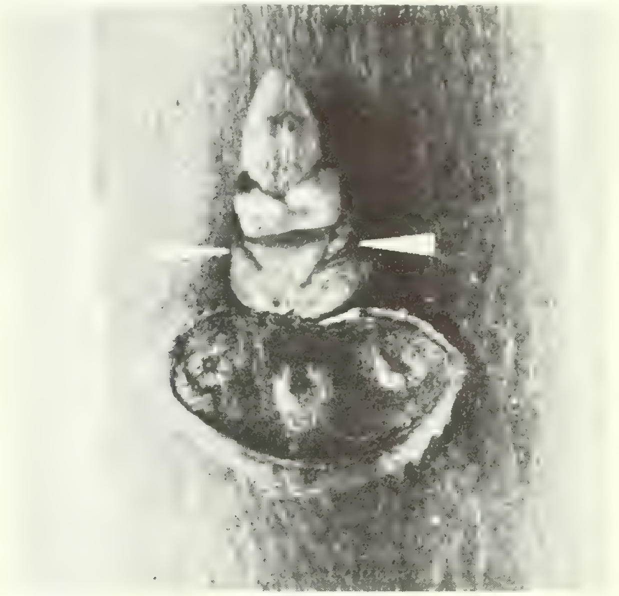

Figure 9.—Slightly elongated axillary bud on a 2-year-old shoot. Arrows point to small collateral buds at base which may later become suppressed buds, X4.

Most of the lateral branches which developed during the first season (preceding year) from the middle or upper nodes grow vigorously, but interspersed among these are several branches of low vigor which die by late summer (fig. 10, C). The collateral buds situated at the base of these low-vigor branches appear to degenerate. But, close examination reveals that whereas the outermost bud scales become necrotic, the buds themselves do not, and they slowly become covered by a periderm (fig. 10, D). Formation of the new periderm disrupts the vascular connection leading to the bud scales and thus speeds their necrosis.

The growth of axillary buds into vigorous or persistent first-order lateral branches with inhibited basal, collateral buds occurs during the first and second years. This is the normal

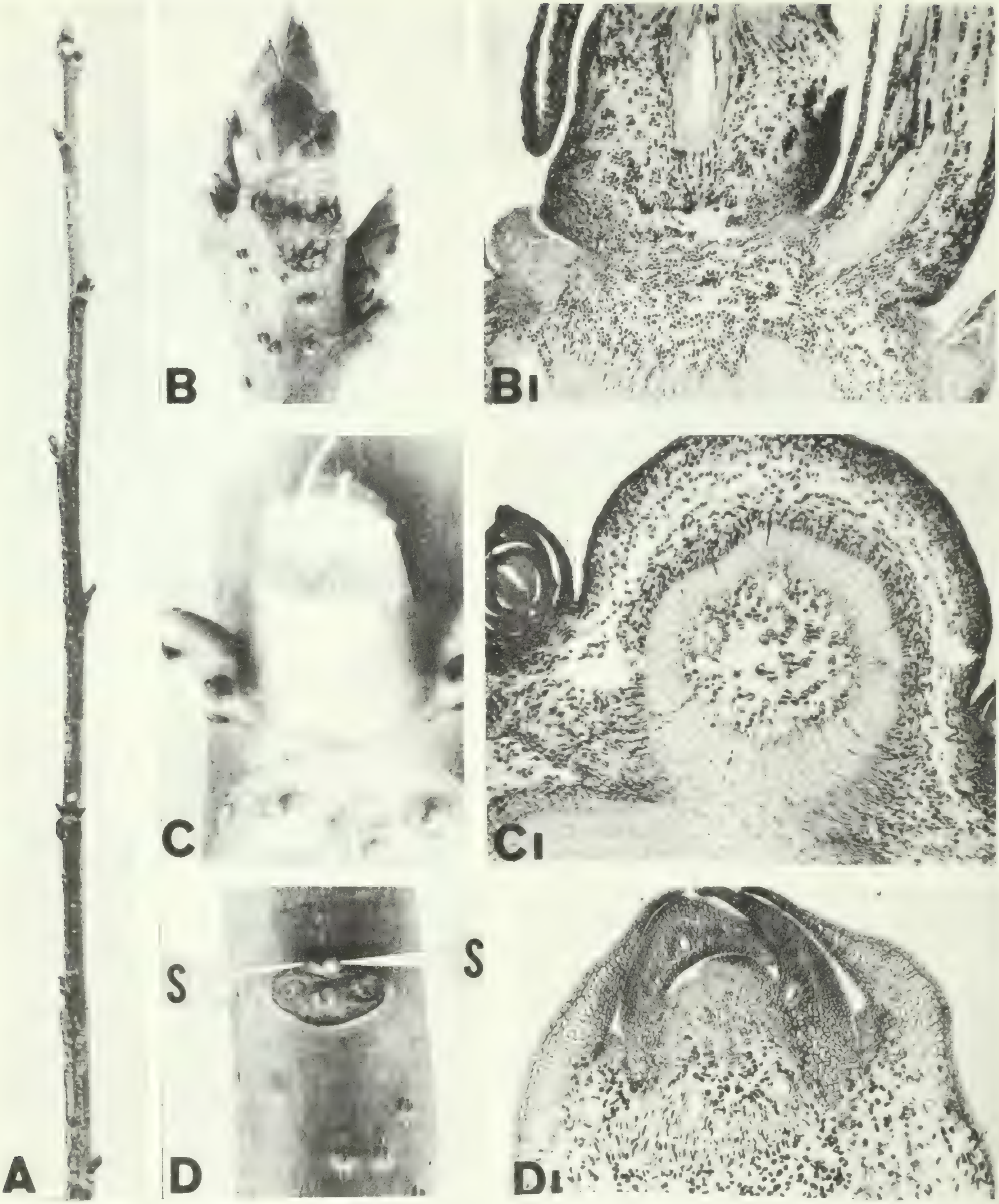

Figure 8.—Pattern of bud development at different levels on the current year's terminal shoot at the end of the growing season. (A) Current year's terminal shoot with extended lateral branches removed; (B) terminal bud and uppermost inhibited axillary buds possessing collateral buds on axils of the basal scale; (C) distinct collateral buds after elongation of the axillary bud; (D) inhibited basal axillary bud with nonvisible collateral buds in axils of basal scales (S); (B_1, C_1, D_1) all photomicrographs of portion of axillary buds showing stages of development of collateral buds at each node, X115.

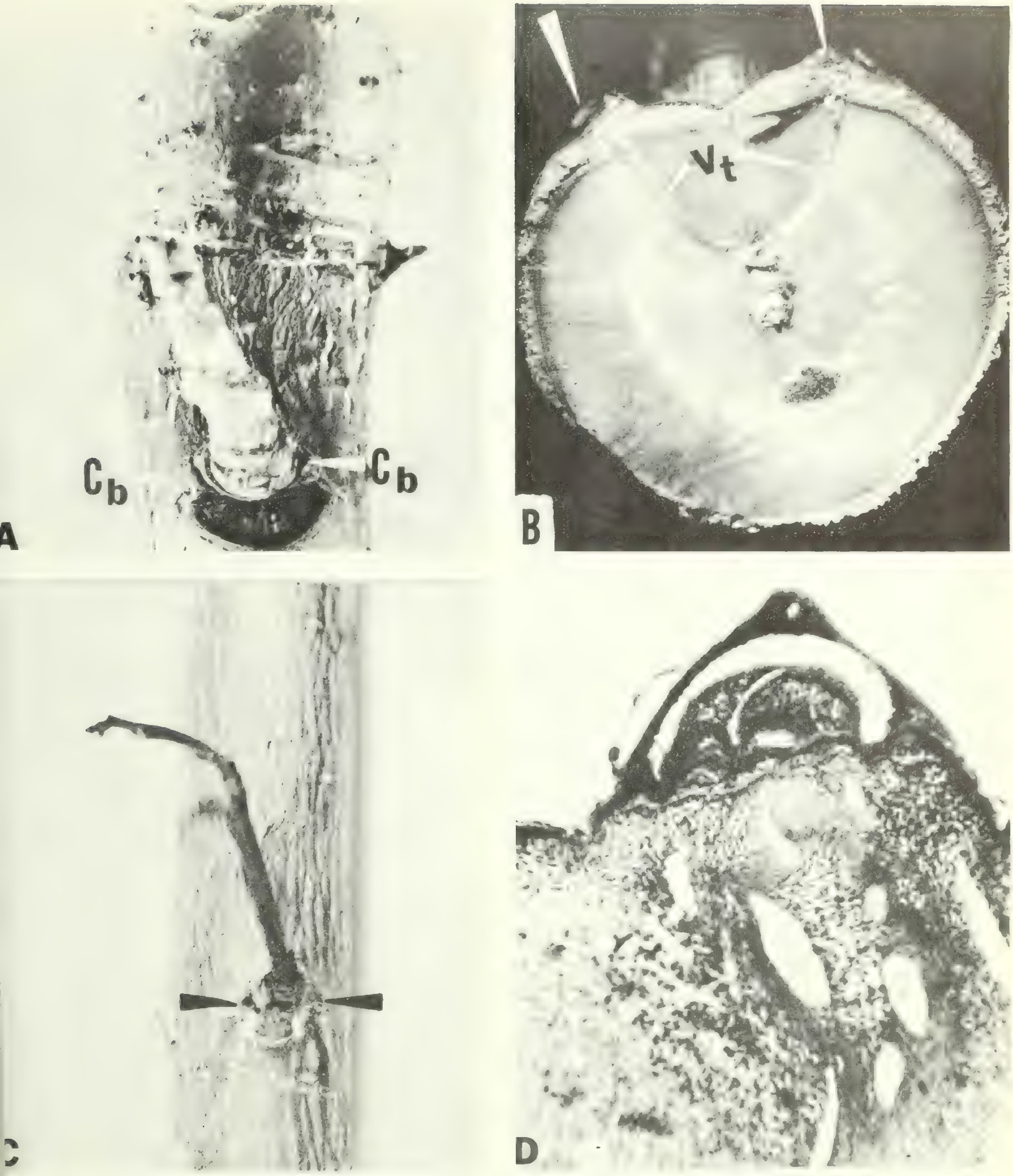

Figure 10.—Elongation of inhibited first-year axillary buds in early spring of the second year and their subsequent development. (A) Release of uppermost axillary buds on previous year's growth. Lateral branch is of poor vigor. Note the partially embedded collateral bud (C_b) and the basal nodes of the above current year's shoot; (B) transverse section of 10, A with arrows pointing to suppressed collateral buds and their vascular traces leading to pith (V_t); (C) basal ephemeral branch from previous year's growth undergoing senescence. Arrows indicate position of partially embedded collateral buds; (D) transverse section at base of 10, C showing partially embedded collateral bud, X150.

pattern of bud development in sweetgum (fig. 11). Axillary buds on these first-order branches, however, do not develop visible collateral buds unless the branch is exceptionally vigorous.

Nodal development on the 2-year-old stem is variable, but a distinct pattern exists. The basal and terminal nodes produce ephemeral lateral branches, and these branches are associated with inconspicuous development of the collateral buds which soon become embedded. For the most part, the other lateral branches grow normally, producing prominent collateral buds at their bases. The size of the collateral buds diminishes basipetally, with those at the top being the largest.

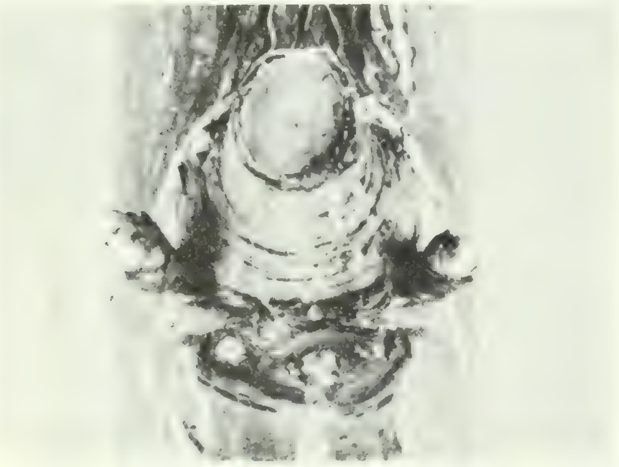

Figure 11.—Normal nodal development along midportion of 2-year-old stem. Note large, conspicuous collateral buds.

Bud and Branch Development — Third Year

The final transition from collateral buds to suppressed buds is quite variable. The lateral branches that grew vigorously during the second year continue to grow during the third year, but the less-vigorous laterals usually die in the third growing season. It is important to note that this natural mortality of lateral branches does not stimulate growth of inhibited collateral buds (cf. fig. 10, C). To the contrary, early mortality of lateral branches promotes early transition to suppressed buds. Artificial pruning has the reverse effect, as will be shown later.

There is no visible elongation of the collateral buds along the 3-year-old portion of the stem, and radial growth during the summer results in the gradual envelopment of these buds by the rapidly expanding periderm. The pattern of envelopment proceeds acropetally from the basal nodes of the 3-year stem to the beginning of the 2-year-old stem. There is, however, noticeable variation in the pattern of bud envelopment mainly associated with the vigor of individual lateral branches. Collateral buds associated with any low-vigor lateral branches on the 3-year-old portion of the stem will be enveloped by the periderm much sooner than those associated with vigorous laterals; hence, all collateral buds on a 3-year-old stem do not become embedded simultaneously. At any given node, however, both collateral buds are affected in a similar way.

The collateral buds associated with lateral branches that continue to grow during the third and subsequent years frequently develop from their basal scales a single, small leaf which dies or aborts in early summer. However, on stems with exceptional vigor and rapid growth, where the usual transition to suppressed buds would not be expected to begin for at least 4 to 5 years, the collateral buds retain this small leaf, or occasionally two leaves, until the latter part of the summer. These buds undergo little internodal elongation (fig. 12) and, in external appearance, resemble the spur shoots so common in *Malus, Pyrus, Fagus,* and numerous other woody species.

An extremely interesting feature of these vigorous collateral buds is their tendency to produce other buds in scale axils in the exact manner and position as they themselves were produced. These, too, may readily become suppressed buds (fig. 13). The bud, in the process of becoming embedded in figure 13, is not adventitious in origin. Serial sections clearly established the distinct branching of the vascular strands leading back to the pith. These bud-scale buds[3] were sectioned early in their ontogeny, but in later stages of development one can follow their vascular traces into those of the original axillary bud.

Except for the variations just noted, where position and vigor play an important part in the envelopment by the periderm, collateral buds normally follow a pattern of acropetal envelopment. In other words, those buds at the base of the third-year portion are embedded first; higher on this portion of the stem, complete envelopment takes place the following year. Figure 14 (page 10) shows the normal appearance of the nodes at various levels on the 3-year-old portion of the stem at the end of the growing season. There is a striking similarity in the appearance of the collateral buds in figure 14, B and the basal axillary buds in figure 8, D.

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[3] Buds which form in scale axils rather than foliar leaf axils (Chandler 1947).

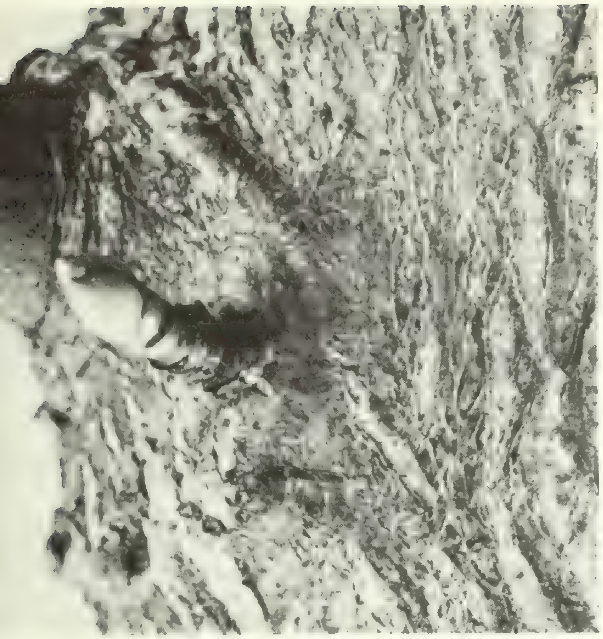

Figure 12.—Collateral bud on 3-year-old portion of a vigorous stem undergoing slight internodal elongation and exhibiting the typical short shoot habit of growth.

Some collateral buds are now embedded in the periderm or bark, but others are still visible. For several years, or as long as the bark remains smooth, the position of suppressed buds under the bark is easily determined. Some of the more vigorous buds, however, never become fully embedded and grow as short shoots[4] for various periods of time.

While sectioning 3-year-old material, branching was observed in which the sister branches were of equal size and the cortex was fully developed into the apex of the apparent dichotomy (fig. 15). This supports earlier observations by Kormanik and Brown (1964) that in addition to buds of bud-scale origin, others may be produced by a true dichotomy of the apex in suppressed buds. Detailed histological examination failed to reveal evidence of typical bud-scale origin, or abortion of the bud apex, as found in other apparent dichotomies. Although this does not prove that true dichotomy is a common feature of suppressed buds, the observation indicates that it may happen.

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[4] A short shoot, as used here, is a particular type of epicormic branch whose bud opens during the growing season and produces a few leaves with little or no internodal elongation.

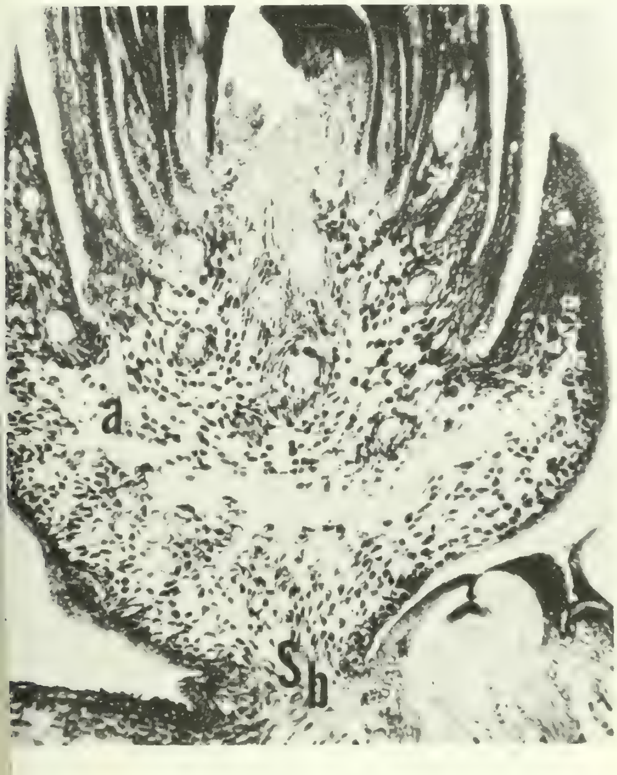


Figure 13.—Longisections of collateral bud on a 3-year-old stem showing (a) scale bud primordia in axils of bud scales, and the scale bud (S_b) set aside earlier, now becoming embedded by the rapidly expanding periderm, X200.

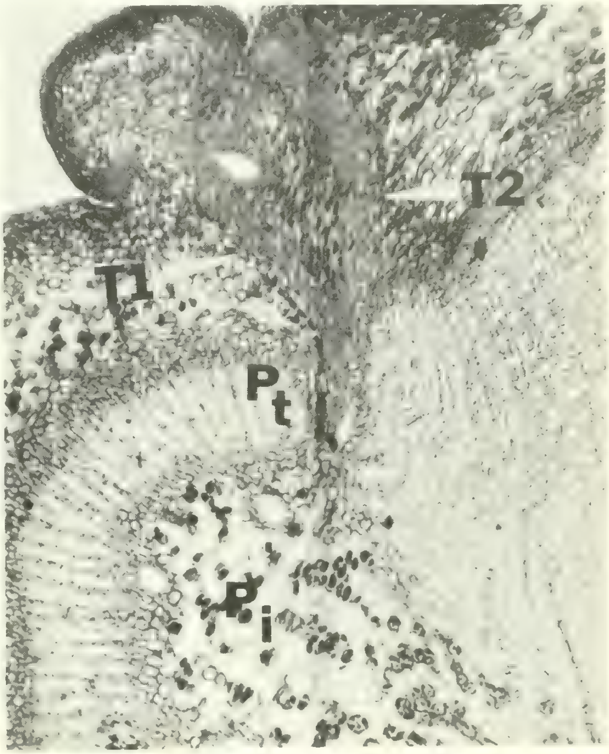


Figure 15.—Apparent dichotomy of collateral buds in the periderm of a 3-year-old stem: pith of axillary branch (P_i); primary trace (P_t); dichotomized traces leading to buds (T1, T2), X176.

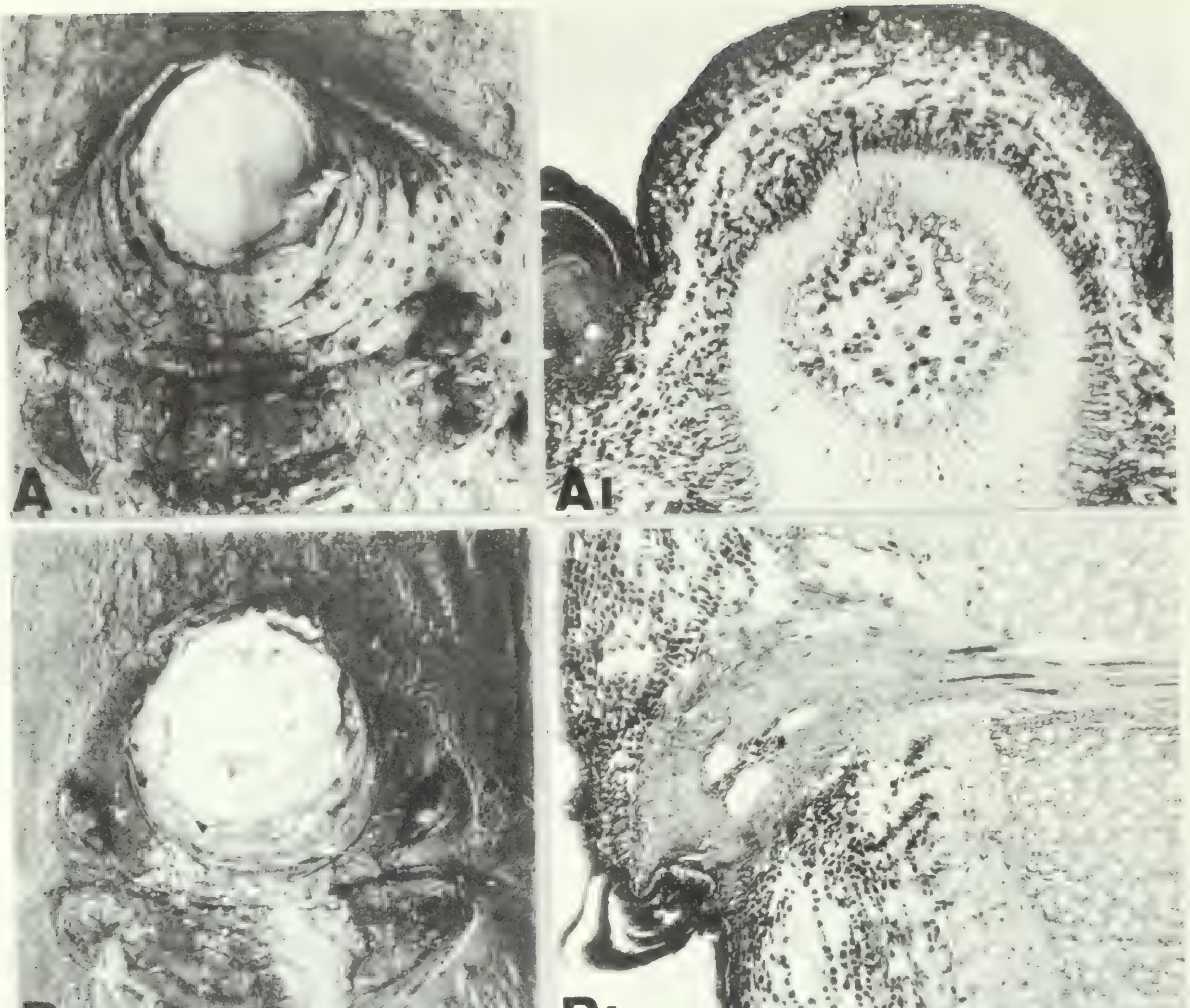


Figure 14.—Transitional stages of collateral buds on 3-year-old stems showing pattern of envelopment by the periderm. (A) Upper nodes, collateral buds beginning transition; (B) middle nodes, collateral buds partially covered by periderm; (C) basal nodes, collateral buds barely visible; (A_1, B_1, C_1) photomicrographs of same developmental stages, X160.

EXPERIMENTAL STUDIES

Disbudding and Pruning Experiments on Young Trees

After studying the ontogeny of the collateral buds and establishing that they were the precursors of the majority of suppressed buds in sweetgum, we became interested in the inhibition mechanism that prevented collateral buds from developing into lateral branches. To study this pattern, potted seedlings were used in the greenhouse, supplemented by young seedlings and stump sprouts in the field.

The first study was conducted in the greenhouse in early spring, beginning with dormant seedlings. Potted 1-0 and 2-0 seedlings were obtained from a mixed local seed source. The treatments imposed were as follows:

Treatment 1—All axillary buds and lateral branches removed, the terminal bud left intact.
Treatment 2—Terminal buds and well-developed lateral branches removed, the axillary buds left intact.
Treatment 3—Well-developed lateral branches removed, complete girdle halfway down stem.
Treatment 4—Well-developed lateral branches removed, a notch cut into the xylem above each node.
Treatment 5—Check — untreated seedlings.

Treatment 1. Removal of all axillary buds resulted in some early swelling of the collateral buds as growth began, but the latter buds failed to elongate. Close examination of the nodes of the seedlings revealed that some collateral buds had been damaged to various degrees by removal of the axillary buds, but the damage was not sufficient to alter their normal development.

Treatment 2. The axillary bud immediately below the decapitated terminal assumed dominance as spring growth began. Its final development was identical to that of any terminal leader. The other axillary buds or branches developed in the same manner as those on the check seedlings. Removal of terminal buds was not effective in breaking dormancy of the collateral buds. However, the removal of well-developed lateral branches resulted in the early swelling of these buds, as in Treatment 1.

Treatment 3. The axillary buds above the girdle developed normally and growth of collateral buds was not stimulated. The first 2 or 3 axillary buds below the girdle developed into lateral branches, but, again the collateral buds were not visibly stimulated. During succeeding weeks, the branch arising from the first axillary bud beneath the girdle in many seedlings assumed a dominant position, even though the original terminal shoot continued growth throughout the growing season.

Treatment 4. When a notch was cut above the node with the axillary bud or a small branch intact, the collateral buds were not stimulated and the axillary bud or branch developed normally. But, where the lateral branch was removed, the collateral buds began to grow soon after the terminal bud resumed growth. The growth thus stimulated lasted only a few weeks, and by early summer the leaves abscissed and new buds were set.

This response, coupled with the results from Treatment 1, is evidence that initial inhibition of collateral buds is controlled by growth substances in the axillary buds or lateral branches; but on these young trees, growth can also be checked or modified quite readily by rapidly growing shoots above.

Disbudding and Pruning Experiments on Field Material

During the middle of June, surgical treatments were applied to single stems and groups of sprouts in the field. This material, ranging in age from about 3 to 6 years, included 20 individual trees in each of the following treatments:

Treatment 1—Terminal bud removed.
Treatment 2—Terminal bud plus all lateral branches and axillary buds removed.
Treatment 3—Terminal bud left intact, all lateral branches and axillary buds removed.
Treatment 4—Terminal bud of each lateral branch removed.
Treatment 5—All leaves and axillary buds from selected lateral branches removed.

Within 3 weeks, the source of the growth inhibition of collateral buds was definitely identified in the axillary buds and, later, the lateral branches.

Removal of the terminal bud had little effect on collateral buds anywhere on the stem. The first axillary bud below the decapitated apex grew vigorously and within 2 weeks resembled a true terminal leader; i.e., the single axillary buds at each node on a terminal leader have visible collateral buds, whereas in lateral branches no visible collateral buds are developed.

Treatments 2 and 3 resulted in a rapid extension of most of the collateral buds, but, no differences in growth response of collateral buds could be detected between the two treatments.

Treatment 3 was again applied to many stems throughout the latter part of June and July, and the removal of a single lateral branch always stimulated the release of its associated collateral buds. This was true even after the collateral buds had become suppressed and were no longer visible on the bark surface. From these studies it is apparent that actively growing lateral branches exercise complete control over the growth and development of collateral buds at their bases, although such buds may now be located on the main stem due to their displacement by radial growth of the stem. In distinct contrast, natural pruning normally does not stimulate the release of collateral buds associated with the senescent branch, which indicates that vigor, along with a rapid shift in metabolism affecting the levels of growth factors at that particular locus, are important in releasing suppressed buds from inhibition. A similar response is obtained with artificial pruning on larger open-grown trees. For example, the pruning of a single branch may cause the release of several suppressed buds beneath it, although these buds may not necessarily be those originally derived from the collateral buds at the base of the pruned branch.

Treatments 4 and 5 failed to stimulate development of the collateral buds on treated branches, indicating again that removal of the entire branch was essential to release these buds from inhibition.

OBSERVATIONS ON DEVELOPMENT AND DISTRIBUTION OF SUPPRESSED BUDS ON TREE BOLES

Continued Formation of Suppressed Buds

Suppressed buds are continually formed during the life of the tree, although they go unnoticed until released as epicormic branches. Years after the loss of lateral branches from natural pruning, the original suppressed buds, through the repeated branching of scale buds, give rise to myriads of suppressed buds in the inner and outer bark. Thus, suppressed buds may occur at any radial position adjacent to the cambium or just under the bark surface. They may occur in pairs or clusters (fig. 16, A), or they may be solitary (fig. 16, B). Pairs or clusters of buds are usually found near the bark surface, whereas single buds are most common nearer the cambium. Suppressed buds of secondary origin can generally be found under the bark, below or at either side of an epicormic branch or short shoot (fig. 16, C). Their apical meristems are sometimes oriented almost tangentially rather than radially, as would be expected (fig. 16, D).

To learn more about the continued formation and distribution of suppressed buds in larger sweetgums, we felled and sectioned numerous trees, ranging from 20 to 80 years of age and from 6 to 26 inches in diameter. The entire bole was sectioned into transverse disks, 1 to 2 inches thick, from the stump to base of the live crown. In examining these disks for bud traces, it soon became apparent that in most trees a period exists when epicormic branches or short shoots are most prevalent on the bole. This period varies, but it is most common when the trees are from 6 to 10 inches in diameter. Older and larger trees with thicker bark actually contain more suppressed buds per unit area than younger trees because of repeated branching of suppressed buds. These buds, however, are not normally released to form short shoots or epicormic branches unless some sudden stimulus is applied, such as pruning, girdling, or releasing the trees from competition by thinnings or improvement cuttings.

One explanation for the occurrence of numerous epicormic branches on trees 6 to 10 inches in diameter is the high state of vigor usually possessed by young trees of this size. At this age, the typical epicormic branch is relatively inconspicuous, and morphologically it may range in size and growth habit from a typical short shoot (fig. 17) to [rarely] a well-developed long shoot.

The short shoot expression of an epicormic branch in sweetgum varies from almost sessile to a stalk 2 to 3 inches long. Short shoots less than 1 inch long generally produce only a single leaf each year, whereas the longer ones produce two or three leaves (cf. fig. 17). It is only after stimulation that they assume the characteristic growth pattern of a long shoot. This growth pattern, so prevalent in ginkgo, larch, and many angiosperms (cf. Büsgen and Münch 1929), is reversible at any time, as shown

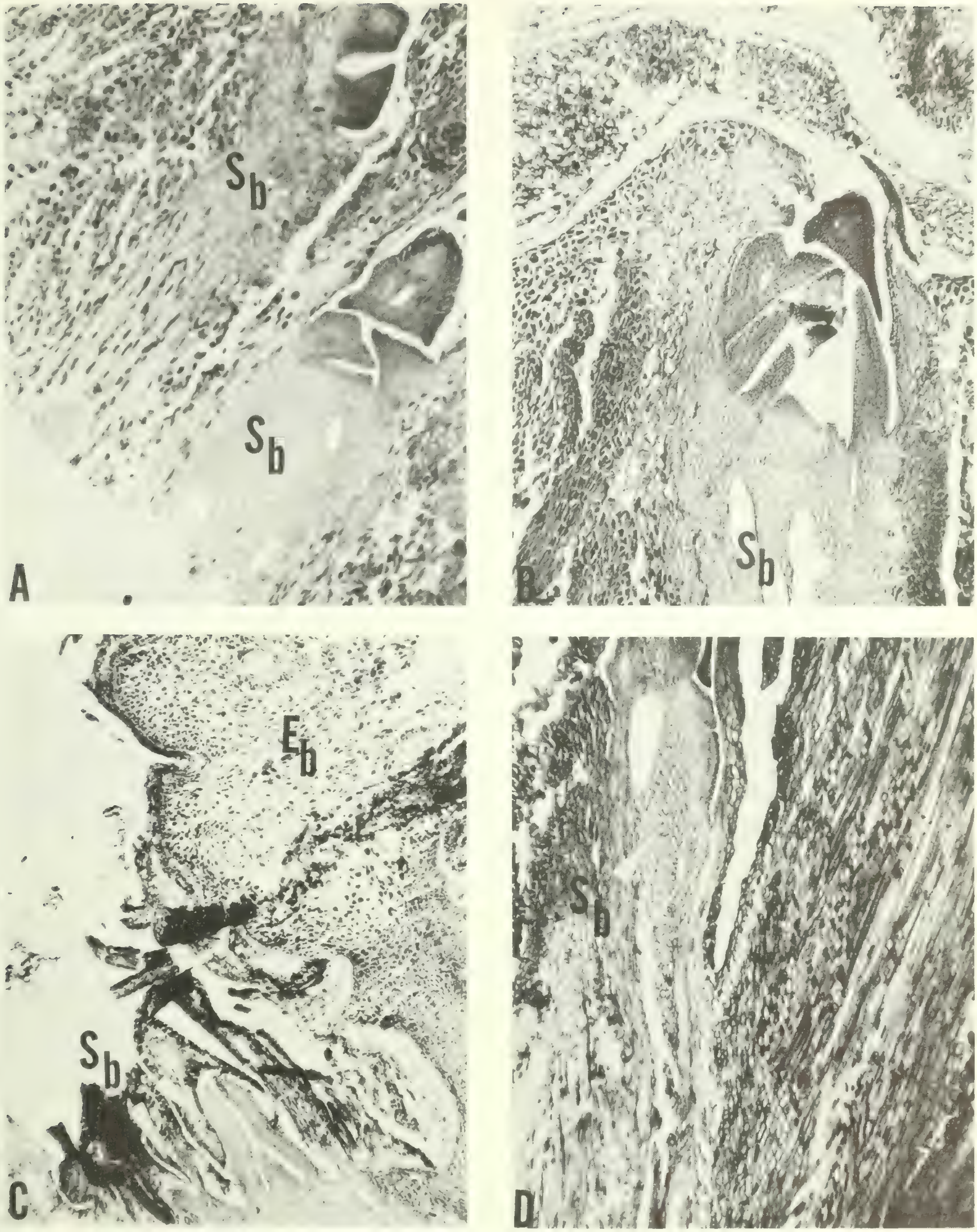


Figure 16.—Occurrence and position of embedded buds in the periderm of older trees. (A) Two adjacent embedded buds (S_b) lying in outer margin of non-functional phloem, X158; (B) single bud (S_b) lying deep in periderm near cambial zone, X158; (C) two adjacent buds (S_b) lying in outer bark below an epicormic branch (E_b), X136; (D) tangentially-oriented bud (S_b) in older phloem tissue, X158.

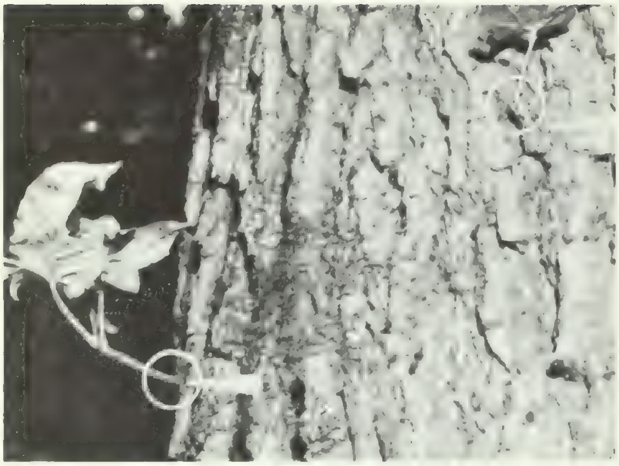


Figure 17.—Typical short shoots arising from embedded buds exhibit a pattern of leaf development related to the size of the shoot.

in figure 18. Here, after existing as a short shoot for a number of years, it was stimulated in its internodal elongation for 1 or 2 years, after which it reverted to the growth habit of a typical short shoot.

Once a suppressed bud resumes growth to become a short shoot, it may be replaced by two or more bud-scale buds that are left behind to form suppressed buds (cf. fig. 16, C). This undoubtedly is the reason that pairs or clusters of suppressed buds are so common near the bark surface, whereas single buds are more common deeper in the periderm.

The typical short shoots of sweetgum are often found in bark fissures on older trees and may be easily overlooked by the casual observer during the dormant season. Frequently, suppressed buds themselves will produce one small leaf annually for a number of years yet remain covered by the outer bark. We first observed this when we examined trees during the dormant season and selected individuals which had few short shoots visible on the bark surface. In June on some of our selected trees, however, single leaves were found scattered over the bole. Examination at this time revealed that some bud apices were protruding slightly above the bark surface and may not have been observed during the dormant season. In most cases, however, the suppressed buds associated with these leaves were completely embedded in the outer bark but could easily be exposed with a knife blade. A thorough check of many sweetgum trees revealed this type of leaf emergence to be common. Presently, it is not known how long this stage of development continues for any given bud, or whether a bud in this stage can become completely inhibited or continue growth and become a short shoot. It is, however, likely that either condition can occur, depending upon the balance of physiological factors affecting bud growth and inhibition.

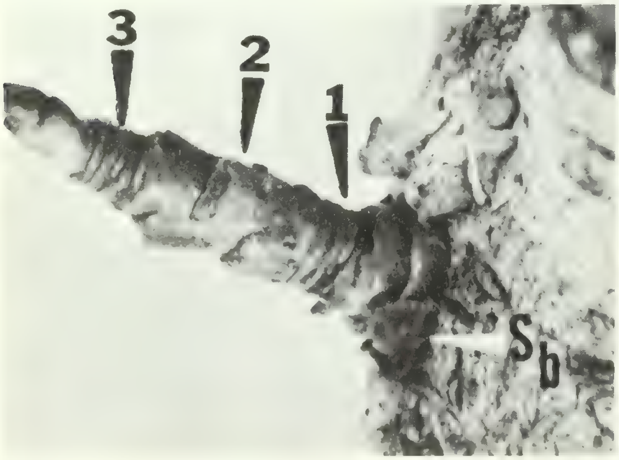


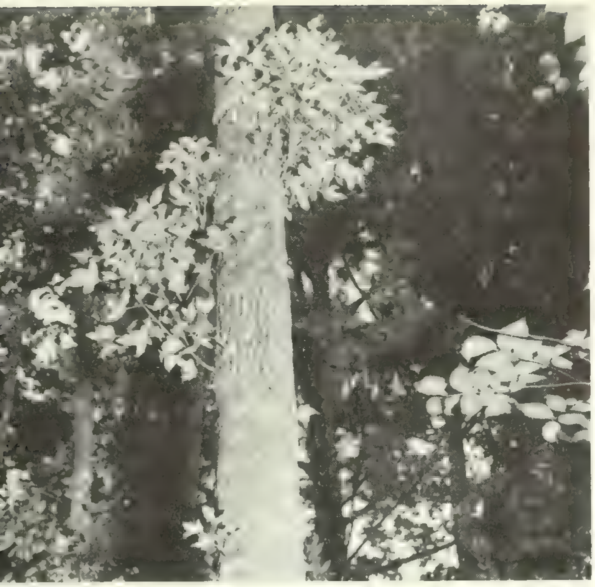
Figure 18.—A short shoot with growth extensions (1, 2, 3) made in successive years. Note extension of the second year's internodes, and also the formation of an additional suppressed bud at the base of the short shoot (S_b).

Eruption of Suppressed Buds

We know from our present work that pruning live branches stimulates the eruption of suppressed buds, and also, in some rare cases, stimulates the growth of short shoots into long shoots. We also know that suppressed buds are stimulated by the death or removal of adjacent trees. Preliminary work indicates that heavy applications of fertilizers to young sweetgum may also stimulate development of suppressed buds.

During 1 year we forced the profuse eruption of epicormic branches on sweetgum by placing complete or partial girdles at several locations on the stem (fig. 19). The physiological effect of girdling is so pronounced that apparently all suppressed buds within a given area are stimulated so that clusters of branches are formed beneath the girdles (fig 20).

Paired trees girdled in this study were chosen so they were of the same age, diameter, and crown class; but one tree in each pair had smooth bark characteristics and the other had deeply fissured bark. Trees ranged from 8 to 14 inches in size and were average in form. None had elongated epicormic branches. Some were completely free of visible short shoots along the first 16-foot log and others had as many as 26. After girdling, epicormic branches were as numerous and vigorous on those trees



igure 19.—Eruption of numerous suppressed buds into epicormic branches following girdling shows a fairly definite phyllotaxic arrangement, even on old stems.

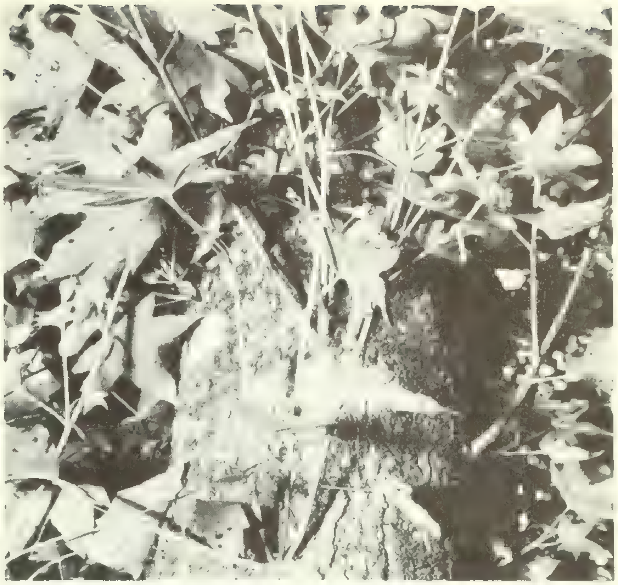


Figure 20.—Extension of numerous epicormic branches from localized areas, indicating eruption of numerous suppressed buds at these loci.

vithout short shoots as on those which had hese structures before treatment.

Each epicormic branch produced beneath a irdle had the bud characteristics of a terminal eader; i.e., each node had an axillary bud plus wo collateral buds. As previously noted, first rder lateral branches of young sweetgum trees ack collateral buds except as they assume the erminal position. An intensive check of numerous older epicormic branches on untreated trees showed that they also resembled terminal leaders with respect to bud characteristics. On 3-year-old portions of these epicormic branches, collateral buds had become suppressed and were being covered by the periderm. Other than this, the gross morphological features of epicormic branches on older trees were identical to those observed on the young terminal shoots, described earlier.

DISCUSSION

The general concepts of epicormic branches nd suppressed buds are not new, but specific nformation on the origin and development is till lacking for most species. The origin of uppressed buds in sweetgum has been followed n detail here. The majority of these buds can e traced to the formation of collateral buds in he basal scales of axillary buds during primary shoot growth. All nodes of the current ear's terminal shoot contribute collateral buds, ven those axillary buds at the base which were nconspicuous (cf. fig 8, D). In other species, ot all nodes of the terminal leader contribute ignificantly to suppressed bud formation or ven axillary bud formation. For instance, üsgen and Münch (1929) reported that basal odes on the current year's terminal leader of *cer pseudoplatanus* have axillary buds that appear o be lacking, but in fact remain small or uneveloped and some die during the spring. Vith sweetgum, however, these nodes can each dd initially two accessory buds which, because of the little internodal elongation on the shoot at this point, result in numerous suppressed buds in a small area. More recently, Church and Godman (1966) reported that buds destined to become suppressed are those few axillary buds formed at the base or at the tip of the current year's shoot. They do, however, point out that dormant buds may be present at internodes at the base of lateral branches, and they believe these and other "dormant" buds always remain external to the bark. These authors were also able to distinguish between "healthy dormant buds" and dead ones on the basis of external appearance. In sweetgum, we have found that collateral buds become suppressed buds embedded within the bark and are not externally visible on older trees. Furthermore, on sweetgum, what may appear to be collateral buds of low vigor are often transitional stages leading to complete embedding of collateral buds within the bark (cf. fig. 10).

Because suppressed buds have vascular tissue easily traced to the pith, their origin during primary shoot development as accessory buds is obvious. Jacobs (1955) points out that "dormant buds" do arise at every node on eucalypts, as we also found on sweetgum. However, in eucalypts, they may exist as only unorganized meristematic tissue or may develop further into distinct accessory buds. Subsequently, after leaf fall, a strand of tissue capable of producing buds grows radially outward from the base of the petiole attachment. These "bud strands" are the source of epicormic branches in this species. Jacobs also points out that these bud strands frequently branch and produce other bud strands, as Hahne (1926) reported. Berntsen (1961) reported that epicormic branches in red alder *(Alnus rubra)* develop from "dormant bud strands" or "bud-producing tissue." In most suppressed bud studies, the morphological description of suppressed buds has been made with sections of stem cut with a saw or knife. Specimens treated in this manner do look like "bud strands," with little or no organization apparent. Histological observations in sweetgum, however, clearly reveal that suppressed buds in this species have a typical bud organization (cf. fig. 16). Furthermore, we believe that in the axils of the foliar-like structure of suppressed buds, definite immature buds exist, which under proper stimuli account for the frequently reported "branching" of "bud strands" or "bud-producing tissue" in both forest and fruit trees. The confusion about the morphology of suppressed buds can probably be attributed more to the lack of detailed histological examinations in different species than to a radical difference in their morphology.

Jacobs (1955) reported that pronounced stimulation of epicormic branches in eucalypts results in clumps of epicormic branches in individual loci because several "bud strands" are present at that point. This same response can be obtained with stem girdles in our native hardwoods. We feel, however, that clumping at different loci occurs because the girdling stimulus releases the suppressed bud as well as its associated buds or bud primordia. It is possible for nests of suppressed buds lying subjacent to each other to produce two clumps of epicormic branches in close proximity (cf. figs. 16, A and 20).

Clark (1955) and Berntsen (1961) have reported that pruning trees does not necessarily result in clear lumber because either dormant buds or bud strands will produce epicormic branches which are serious degraders in lumber. These bud traces extend back to primary tissue, indicating they were once accessory buds on the primary terminal shoot. This response to pruning can be observed on almost any of our important hardwood timber species where live-branch pruning has occurred along powerline rights-of-way.

In sweetgum, the axillary bud, and later the resulting lateral branch from it, is the primary source of inhibition of accessory buds. After the inhibited accessory buds become displaced to the main stem and become suppressed buds, the living branch still is the primary source of inhibition. If artificially removed, the suppressed buds will form either long- or short-lived epicormic branches, as in many other species. Natural pruning in sweetgum does not stimulate suppressed buds to grow into vigorous long epicormic branches. However, as the lower crown of normally developing sweetgum loses its vigor and natural pruning takes place, there is a pronounced increase in number of short shoots, both within the lower crown and for some distance below it. The release of suppressed buds by the receding crown may, in part, explain the abundance of short shoots on vigorous trees 6 to 10 inches in diameter.

Epicormic branches in this species may well be classified as long shoots (cf. figs. 19 and 20) or short shoots (cf. fig 17). The normal expression in undisturbed sweetgum stands is the short shoot habit. Indeed, it may be the typical expression on most forest species. It is only following abnormal stimulation, such as logging damage, release, girdling, etc., that the typical long epicormic branches normally develop. The resulting growth habit (long or short shoot) to a great extent may be influenced by the tree's environment.

Church and Godman (1966) indicated that "stalked buds" or "dormant buds" always remain external to the bark. They reported that these short shoots have been found on 50-year-old trees and they could persist much longer. Short shoots on sweetgum, however, are short lived. Numerous dead short shoots can generally be found on most sweetgum stems, especially on those less than age 35. Death of the short shoots on these younger trees is frequently followed by the eruption of other suppressed buds. Early work by Areschaug in 1877 (Büsgen and Münch 1929) indicates that death of these short shoots[5] is characteristic. He states: "in my opinion every dwarf shoot series must die if it is not interrupted from time to time by regeneration shoots." We agree with this observation. It is not known, however, what physiological or environmental factors cause the short shoots periodically to exhibit slight internodal elongation and thus remain vigorous (cf.

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[5] He referred to them as dwarf shoots.

gs. 17 and 18). Light may be one of the limitng factors, and death of adjacent trees may rovide the stimulus needed to release the short hoots.

The physiological mechanism controlling the nhibition of suppressed buds is usually exlained in terms of basipetally transported uxin. Thus artificial pruning removes the ource of auxin coming from the growing apex nd leaves, thereby releasing the buds from inibition at the base of the shoot. Likewise, uppressed buds may be released from inhibiion below a bark girdle because such treatment locks the basipetal flow of auxin in the phloem. o explain the release of suppressed buds from nhibition solely on the basis of an auxin mechnism is undoubtedly too simple. For example, achs and Thimann (1967) have demonstrated he role of cytokinins in the release of lateral uds from inhibition in herbaceous plants, and t is likely that a similar mechanism exists in voody plants. The problem is considerably nore complicated in woody plants, however, beause the time interval between the initiation nd release of inhibited buds may extend over nany years, and involve periods of dormancy nd changing nutritional levels within the tree.

A problem of immediate practical value is he selection of individual trees which are apparently superior in their quality to keep suppressed buds inhibited. If the buds capable of producing epicormic branches on all species were always visible on the bark surface, as Church and Godman reported (1966) for sugar maple, selection against this trait would be relatively simple. However, girdling experiments with older sweetgum, as well as seven other species, indicate that practically all long epicormic branches that develop following treatment originate from suppressed buds and not from short shoots or buds visible on the bark surface. Furthermore, we have found that established short shoots on sweetgum, even when released by girdling, will not develop into typical epicormic branches in one growing season, as do those developing from suppressed buds.

If selections are to be made solely on external appearance in sweetgum, i.e. the absence of visible short shoots, the selections should be made while the trees are 6 to 10 inches in diameter. As pointed out earlier, the appearance of larger trees can be quite misleading. We have observed extremely few 6- to 10-inch diameter sweetgums that we would rate as superior for this single trait. We have, however, observed numerous larger trees that appear superior, especially during the dormant season.

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COMPARING THE FOREST FLOOR AND SURFACE SOIL BENEATH FOUR PINE SPECIES IN THE VIRGINIA PIEDMONT

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by

Louis J. Metz, Carol G. Wells, and Paul P. Kormanik

In March of 1945 a species comparison study was established on the Lee Experimental Forest in Buckingham County, Virginia. The purpose of the study was to determine which of four conifers—loblolly pine (*Pinus taeda* L.), shortleaf pine (*P. echinata* Mill.), Virginia pine (*P. virginiana* Mill.), and white pine (*P. strobus* L.)—would be the most desirable species for planting on poorer upland Piedmont sites where hardwood establishment is generally unsuccessful.

The study reported here was undertaken to determine if the four pine species produced different forest floors, and if the trees modified the surface mineral soil to different extents.

The plantings, consisting of 10 randomized blocks, were made on abandoned fields in the same stage of plant succession, i. e., broomsedge (*Andropogon* spp.) with scattered pine reproduction. No maps were prepared and no analyses were made on the soils before the study was begun. Trees were measured periodically; the 1961 measurements are shown in table 1. This table is reproduced from a previous report by Kormanik and Hoekstra,[1] where more detail on the survival and growth of the plantings can be found.

Two of the most striking visual differences among these plantations presently are the understory and the forest floor. Beneath white pine the understory is sparse, consisting mainly of ericaceous plants such as teaberry (*Gaultheria procumbens* L.) and pipsissewa (*Chimaphila maculata* (L.) Pursh). Under the other three pine species the understory is more typical of this area—oaks (*Quercus* spp.), red maple (*Acer rubrum* L.), dogwood (*Cornus florida* L.), poison ivy (*Rhus toxicodendron* L.), various species of the genus Vaccinium, plus an assortment of minor vegetation, most noticeable of which is honeysuckle (*Lonicera japonica* Thunb.) and the genus Viburnum. The forest floor under the loblolly pine appears appreciably thicker than under the other pines, and an almost continuous H layer has developed. Discontinuous H layers are evident beneath the shortleaf, white, and Virginia pines but they are thin and it is difficult to measure their thickness.

METHODS

Of the 10 original blocks established, five were not used because of the excessive variability of surface soil depth and texture. The blocks used in this study were quite homogeneous with respect to soil—all were classified as Tatum very fine sandy loam. The individual plots for each species in each block measured 1 by 2 chains and contained 242 trees at a spacing of 6 by 6 feet. Sampling was confined to the area inside the center 30 trees, approximately 720 square feet. Ten random sampling points were selected in each plot. At each

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[1] Kormanik, P. P., and Hoekstra, P. E. A comparson of loblolly, white, Virginia, and shortleaf pine in the Virginia Piedmont. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-11, 3 pp. 1963.

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Table 1.—Average survival, height, diameter, and basal area of trees in a 16-year-old species comparison test, Buckingham County, Virginia

Species	Survival	Height	Diameter	Basal area per acre
	Percent	*Feet*	*Inches*	*Sq. ft.*
Loblolly pine	76 (76)[1]	43 (44)	5.7 (5.8)	167 (175)
White pine	68 (65)	40 (40)	5.7 (5.9)	145 (142)
Virginia pine	74 (78)	37 (37)	4.8 (4.8)	118 (130)
Shortleaf pine	80 (80)	35 (37)	4.6 (4.9)	124 (129)

[1] Values in parentheses are averages for the five plots used in our study.

of these 10 points on each plot, both the forest floor and surface 3 inches of mineral soil were sampled in July and August of 1962.

Forest Floor: A 1-sq.-ft. frame was placed on the forest floor and a knife moved along the inside edge. The layers were separated as the floor was picked up and placed in paper bags. All samples had L and F layers, and some also had a thin H layer. The following criteria were used to divide the floor into layers. The L layer was all relatively undecomposed material dropped since the previous September. The F layer was partially decomposed material, still recognizable as to origin. This means there was a gradation from off-colored, whole needles near the L layer to bits of broken, partially decomposed needles (1/16 inch or less in size) near the bottom of the layer. The H layer was well decomposed organic matter, unrecognizable as to origin.

Mineral Soil: Mineral soil was collected at three depths: 0-1 inch, 1-2 inches, and 2-3 inches. Samples were collected with a push tube from soil bared when the forest floor was collected. Ten cores were taken at each square-foot sampling area and the material, separated by depths, was composited. Bulk density samples were collected at four random points in each plot using methods developed by Lutz.[2]

Laboratory Methods

The samples of forest floor material were ovendried at 60° C., weighed, and ground. Mineral soil samples were air dried and passed through a 2-mm. sieve; subsamples were then powdered for analyses of organic matter and nitrogen.

Calcium, Mg, K, and P were determined in forest floor samples with the following procedures. A 2-g. ovendry sample was ashed at 400° C. for 4 hours. The ash was taken up in 10 ml. of 8 N HCl, diluted to 100 ml., and filtered to make the "base" solution. Potassium, Ca, and Mg were analyzed on a flame spectrophotometer. Potassium was determined in the "base" solution, and Ca and Mg were determined in a 25-ml. aliquot by the method of Wells and Corey.[3] Phosphorus was determined in a 10-ml. aliquot by the molybdovanadate method.[4] Total N in the forest floor material and mineral soil was determined by the Kjeldahl method.

Ash content of forest floor was determined by burning an ovendry sample at 600° C. for 4 hours. All values for concentration of elements in the forest floor are on an ash-free basis.

Exchangeable K, Ca, and Mg were extracted from the mineral soil with 1.0 N NH_4OAc (buffered at pH 7) and analyzed with a Beckman DU spectrophotometer. Readily soluble P was extracted by the Truog method (0.002 N H_2SO_4 buffered at pH 3); pH was determined in a paste with a glass electrode; and carbon was determined by the dry combustion method on a carbon induction apparatus.[4]

A known volume of mineral soil was ovendried to a constant weight at 105° C. for bulk density determinations. Bulk density values were used to convert concentrations to pounds per acre.

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[2] Lutz, J. F. Apparatus for collecting undisturbed soil samples. Soil Sci. 64: 399-401. 1947.

[3] Wells, C. G., and Corey, R. B. Elimination of interference by phosphorus and other elements in the flame photometric determination of calcium and magnesium in plant tissue. Soil Sci. Soc. Amer. Proc. 24 (3): 189-191. 1960.

[4] Jackson, M. L. Soil chemical analysis. 498 pp. Englewood Cliffs, N. J.: Prentice-Hall, Inc. 1958.

Statistical Methods

Analysis of variance, with the following sources and degrees of freedom, was used to test for a species effect for each of 96 responses:

Source	d. f.
Blocks	4
Species	3
Experimental error	12
Sampling error	180

Bulk density of the mineral soil was analyzed the same way, except that sampling error had 60 degrees of freedom. No statistical analyses were run for the percentage values of elements in the H layer.

In addition, Tukey's w-procedure as given in Steel and Torrie[5] was used to test for significant differences between all possible pairs of species means.

RESULTS

Weight measurements confirmed visual observations—the forest floor beneath the loblolly stands was appreciably heavier than that beneath the other species (table 2). The L layer was heaviest beneath the loblolly, and it was the only species with an H layer thick enough to be measured or collected. Even here, the H layer was discontinuous—it was collected in 10 samples on one plot, was missing on one plot, and on the others it occurred in nine, eight, and three samples of the 10 collected. Climatic conditions of the Piedmont are such that a deep H layer is seldom found in upland forests.

The loblolly forest floor was also thicker than under the other species. When the weight of the total floor was divided by the depth, however, we found that unit weights for loblolly, shortleaf, and white pine floors were comparable, and that Virginia pine floor was considerably heavier. This resulted from the closer packing of the short Virginia pine needles.

The lower parts of the forest floor had higher average pH values than the upper parts. For white pine, the F layer pH was 0.8 unit higher than the L layer. For the other species, the difference was 0.1 or 0.2 pH unit. The only exception was the H layer under loblolly pine—the pH was the same as the L layer and 0.1 unit below the F layer.

The P, Ca, and N percentages were higher in the F layer than in the L layer for all species, and K and Mg were found in greater percentages in the L layer than in the F layer. The weight of P, K, Ca, Mg, and N was much greater in the F layer than in the L layer. This was expected because the volatile matter weight of the F layer is 3 to 6 times greater than the L layer. In the H layer of loblolly stands, the percentages of all elements except Mg were higher than those in L and F layers. The Mg percentage was slightly greater in the L layer than in the other layers. Since the weights of the L and H layers were not greatly different, the weights of nutrients in these layers differed slightly. The only exception was with N, where both the percentage and weight were considerably greater in the H layer.

The bulk density of mineral soil on all plots increased with depth but there were no significant differences between species. As a result, the percentage and weight values for all elements were ranked in the same order among the species.

The primary differences in the influence of species upon mineral soil were for soil reaction, available P, and exchangeable Ca (tables 2 and 4).

Soil reaction was highest beneath white pine, reflecting higher Ca content in the forest floor and 0-2 inch depth of mineral soil. The most acid condition was produced in the 0-1 inch depth under Virginia pine. Species influence upon soil reaction failed to extend into the 2-3 inch depth.

The greatest amount of available P in mineral soil occurred beneath white pine. Even though the percentage P was greatest, the white pine floor had the smallest amount present due to its relatively light weight.

The greatest amount of Ca was found under white pine for the surface 2 inches, and beneath Virginia pine for the 2-3 inch layer. In contrast to the situation with P there was more Ca in the forest floor under white pine than under the other species.

Mineral soil beneath Virginia pine contained the greatest amount of organic matter (OM). For the surface 3 inches of mineral soil, the only significant differences among the factors measured were in the weight of P and Ca between shortleaf and white pines, and in weight of P between white and Virginia pines. There were no

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[5] Steel, R. G. D., and Torrie, J. H. Principles and procedures of statistics. 481 pp. New York: McGraw-Hill. 1960.

Table 2.—Means for properties investigated under four pine species. (Values for concentrations of elements in forest floor are on an ash-free basis)

Layer	Property	Unit	Species			
			Loblolly	Shortleaf	Virginia	White
L	Volatile matter	lb./acre	3,951	2,260	2,113	2,480
	Ash	%	2.76	3.29	2.45	3.86
	pH		4.2	4.2	4.0	4.2
	P	%	.056	.062	.062	.074
	K	%	.081	.137	.137	.097
	Ca	%	.381	.469	.478	.978
	Mg	%	.089	.093	.069	.124
	N	%	.633	.717	.764	.823
	P	lb./acre	2.26	1.43	1.29	1.88
	K	lb./acre	3.30	3.06	2.75	2.47
	Ca	lb./acre	14.93	10.54	10.04	25.11
	Mg	lb./acre	3.48	2.18	1.46	3.07
	N	lb./acre	25.11	16.13	16.16	20.40
F	Volatile matter	lb./acre	14,513	11,265	12,657	7,034
	Ash	%	10.42	13.95	14.51	21.87
	pH		4.3	4.4	4.1	5.0
	P	%	.081	.092	.096	.133
	K	%	.066	.089	.074	.086
	Ca	%	.424	.608	.552	1.022
	Mg	%	.067	.087	.063	.101
	N	%	1.094	1.275	1.540	1.654
	P	lb./acre	11.86	10.09	11.92	9.36
	K	lb./acre	9.33	9.48	9.21	6.09
	Ca	lb./acre	57.96	65.00	68.65	73.24
	Mg	lb./acre	8.45	9.27	7.88	7.13
	N	lb./acre	159.34	142.01	194.08	111.37
H	Volatile matter	lb./acre	3,570			
	Ash	%	31.45			
	pH		4.2			
	P	%	.107			
	K	%	.097			
	Ca	%	.510			
	Mg	%	.085			
	N	%	1.499			
	P	lb./acre	3.61			
	K	lb./acre	3.33			
	Ca	lb./acre	17.47			
	Mg	lb./acre	2.90			
	N	lb./acre	52.80			
L + F + H	Thickness	inches	2.6	1.5	1.1	1.1
	Volatile matter	lb./acre	22,034	13,525	14,770	9,514
	P	lb./acre	17.73	11.52	13.21	11.24
	K	lb./acre	15.96	12.54	11.96	8.56
	Ca	lb./acre	90.36	75.54	78.69	98.35
	Mg	lb./acre	14.83	11.45	9.34	10.20
	N	lb./acre	237.25	158.14	210.24	131.77
0-1 inch	pH		4.5	4.5	4.3	4.9
	P	p.p.m.	3.8	2.9	2.9	4.7
	K	p.p.m.	71	72	89	63
	Ca	p.p.m.	218	167	190	382
	Mg	p.p.m.	29	28	29	42
	N	%	.070	.073	.083	.079
	OM	%	2.94	2.72	3.06	2.87
	P	lb./acre	1.05	0.84	0.82	1.34
	K	lb./acre	19.86	20.84	25.69	18.17
	Ca	lb./acre	60.73	48.38	54.92	108.37
	Mg	lb./acre	7.69	8.13	8.45	11.98
	N	lb./acre	195.6	211.8	238.0	226.7
	OM	lb./acre	8,316	7,888	8,794	8,233
	C/N		25.3	22.0	21.3	20.0

Table 2.—Means for properties investigated under four pine species. (Value for concentrations of elements in forest floor are on an ash-free basis) (continued)

Layer	Property	Unit	Species			
			Loblolly	Shortleaf	Virginia	White
1-2	pH		4.8	4.6	4.6	4.9
inches	P	p.p.m.	2.8	1.9	1.8	3.0
	K	p.p.m.	56	60	92	56
	Ca	p.p.m.	148	114	175	302
	Mg	p.p.m.	24	18	26	29
	N	%	.048	.052	.064	.052
	OM	%	1.92	1.99	2.26	1.89
	P	lb./acre	.87	.59	.56	.91
	K	lb./acre	17.83	18.86	28.47	16.76
	Ca	lb./acre	48.24	35.86	54.08	92.07
	Mg	lb./acre	7.53	5.76	8.11	8.72
	N	lb./acre	155.4	163.9	198.1	158.5
	OM	lb./acre	6,121	6,172	6,882	5,751
	C/N		23.7	22.5	22.0	22.1
2-3 inches	pH		4.9	4.8	4.8	5.0
	P	p.p.m.	2.0	1.4	1.7	2.6
	K	p.p.m.	48	57	95	43
	Ca	p.p.m.	127	103	174	161
	Mg	p.p.m.	20	18	26	24
	N	%	.043	.047	.052	.048
	OM	%	1.67	1.87	1.96	1.74
	P	lb./acre	.63	.46	.55	.78
	K	lb./acre	15.37	18.46	30.16	13.32
	Ca	lb./acre	39.75	33.37	55.74	49.17
	Mg	lb./acre	6.40	6.33	8.33	7.21
	N	lb./acre	136.7	152.4	162.7	148.1
	OM	lb./acre	5,267	5,559	6,156	5,582
	C/N		22.7	23.5	22.8	23.0
0-3	P	lb./acre	2.55	1.89	1.93	3.03
inches	K	lb./acre	53.06	58.16	84.32	48.25
	Ca	lb./acre	148.72	117.61	164.74	249.61
	Mg	lb./acre	21.62	20.22	24.89	27.91
	N	lb./acre	487.7	528.1	598.8	533.3
	OM	lb./acre	19,704	19,619	21,832	19,566
Floor						
+ 0-3	P	lb./acre	20.28	13.41	15.14	14.27
inches	K	lb./acre	69.02	70.70	96.28	56.81
	Ca	lb./acre	239.08	193.15	243.43	347.96
	Mg	lb./acre	36.45	31.67	34.23	38.11
	N	lb./acre	724.95	686.24	809.04	665.07
	OM	lb./acre	41,738	33,144	36,602	29,080
0-1 inch	Bulk density		1.25	1.28	1.26	1.27
1-2 inches	Bulk density		1.42	1.38	1.35	1.34
2-3 inches	Bulk density		1.40	1.44	1.39	1.34

significant differences in the carbon-nitrogen ratio (C/N) with respect to either species or depth of soil.

By combining the weights of elements in the forest floor and the surface 3 inches of mineral soil, we found that loblolly pine had the most P and organic matter, Virginia pine had the most K and N, and white pine had the most Ca and Mg.

The significant differences between species are shown in tables 3, 4, and 5.

DISCUSSION

Forest floors vary in thickness and composition, and separation of the material into specific layers is often difficult. In this study, separation of the lower F layer from the H layer was no simple matter because, rather than a sharp demarcation line, there was a gradual transition between the two. Thus, when comparing organic matter or nutrients of forest floors, the weight of the total floor was a much better criterion than was weight of individual layers.

Table 3.—Significant differences, between four pine species, for weight and chemical properties of forest floor studied

Species	Layer	PROPERTIES[1]		
		Shortleaf pine	White pine	Virginia pine
Loblolly pine	L	Volatile_{wt} **P_{wt}** **N_{wt}** [2]	Volatile_{wt} **$Ash_{\%}$** $P_{\%}$ $Ca_{\%}$ **$Mg_{\%}$** $N_{\%}$	Volatile_{wt} **P_{wt}** Mg_{wt} **N_{wt}**
	F		**Volatile_{wt}** $Ash_{\%}$ pH $P_{\%}$ $Ca_{\%}$ **$Mg_{\%}$** $N_{\%}$	$N_{\%}$
	H	Volatile_{wt} P_{wt} K_{wt} Ca_{wt} Mg_{wt} N_{wt}	Volatile_{wt} P_{wt} K_{wt} Ca_{wt} Mg_{wt} N_{wt}	Volatile_{wt} P_{wt} K_{wt} Ca_{wt} Mg_{wt} N_{wt}
Shortleaf pine	L		$Ca_{\%}$ **Ca_{wt}**	
	F		**$Ash_{\%}$** pH $P_{\%}$ **$Ca_{\%}$** $N_{\%}$	**$N_{\%}$**
	H			
White pine	L			$Ash_{\%}$ **pH** $Ca_{\%}$ $Mg_{\%}$ **Ca_{wt}** **Mg_{wt}**
	F			**$Ash_{\%}$** pH $P_{\%}$ $Ca_{\%}$ **$Mg_{\%}$** **N_{wt}**
	H			

[1] Properties shown in cells are significantly different between the two species which intersect to form the individual cells.

[2] Properties set in boldface are significant at 5% level; all others are significant at 1% level.

When collecting samples of the forest floor, we found great variation—even among samples several feet apart. We attributed this variation to (1) tendency of material to collect in the old field furrows; (2) the sloughing of bark, which creates a thicker floor near the base of trees; (3) our inadvertent inclusion of mineral soil as we scraped up the lowest layer of the floor; (4) the depositing of minerals in the floor by fauna (for example, great quantities of mineral soil that were carried upwards by ants and other insects).

To reduce the weight variation between samples of the forest floor, the percentage volatile matter (100 minus ash percentage) was determined for all organic samples. This percentage was applied to the oven-dry weights, thus all forest floor weights were on a volatile-matter basis. The lower layers of the forest floor had a greater percentage of ash than did the surface layers. For the L layer, with little mineral soil contamination, the ash represented primarily the nonvolatile elements in the organic tissue. For the F and H layers most of the ash weight was mineral matter, even though decomposition of the organic matter increased the concentration of nonvolatile elements in these layers.

There were considerable differences between some of the forest floors studied; differences in the mineral soil were not so great. Since no data are available on soils prior to treatment, it is not possible to ascribe to species all differences now found in the mineral soil. It appears that if soil changes develop along indicated trends, mineral soil under white pine will be higher in Ca, Mg, and available P, and less acid than soils under the other pine species. These changes are indicated by a higher Ca and Mg content of the foliage of white pine. Nitrogen, although slightly higher

Table 4.—Significant differences, between four pine species, for chemical properties of the surface 3 inches of mineral soil

Species	Layer	PROPERTIES[1]		
		Shortleaf pine	White pine	Virginia pine
	Inches			
Loblolly pine	0-1		**pH**[2]	
	1-2			
	2-3			
Shortleaf pine	0-1		**pH** **Ca_{ppm}** **Ca_{wt}**	
	1-2		**pH** **Ca_{ppm}** **Ca_{wt}**	
	2-3		**P_{ppm}** **P_{wt}**	
White pine	0-1			pH Ca_{ppm} Ca_{wt}
	1-2			**pH** **P_{wt}**
	2-3			

[1] Properties shown in cells are significantly different between the two species which intersect to form the individual cells.

[2] Properties set in boldface are significant at 5% level; all others are significant at 1% level.

under Virginia pine, is expected to remain low or become lower in concentration in the mineral soil and continue to accumulate in the forest floor for all species. The greatest N accumulation is expected in the forest floor of loblolly pine.

These stands are young and have had a relatively short time to produce a stable forest floor and influence the mineral soil. Sampling these plantations when they are older will be necessary if we are to draw more definite conclusions about the influence of these trees on the mineral soil.

Table 5.—Significant differences, between four pine species, for properties of the combined forest floor and surface 3 inches of mineral soil

Species	Layer	PROPERTIES[1]		
		Shortleaf pine	White pine	Virginia pine
Loblolly pine	L+F+H	$\mathrm{Volatile}_{wt}$ $\mathbf{P_{wt}}$ $\mathbf{Mg_{wt}}$ [2] N_{wt} Thickness	$\mathrm{Volatile}_{wt}$ $\mathbf{P_{wt}}$ Mg_{wt} N_{wt} K_{wt} Thickness	$\mathbf{Volatile_{wt}}$ $\mathbf{K_{wt}}$ Mg_{wt} Thickness
	0-3 inches			
	L+F+H + 0-3 inches	$\mathbf{P_{wt}}$ $\mathbf{OM_{wt}}$	$\mathbf{P_{wt}}$ OM_{wt}	
Shortleaf pine	L+F+H			
	0-3 inches		$\mathbf{P_{wt}}$ $\mathbf{Ca_{wt}}$	
	L+F+H + 0-3 inches		$\mathbf{Ca_{wt}}$	
White pine	L+F+H			N_{wt}
	0-3 inches			$\mathbf{P_{wt}}$
	L+F+H + 0-3 inches			$\mathbf{OM_{wt}}$

[1] Properties shown in cells are significantly different between the two species which intersect to form the individual cells.

[2] Properties set in boldface are significant at 5% level; all others are significant at 1% level.

Effect of Competition on Survival and Height Growth of Red Oak Seedlings

by

Donald E. Beck

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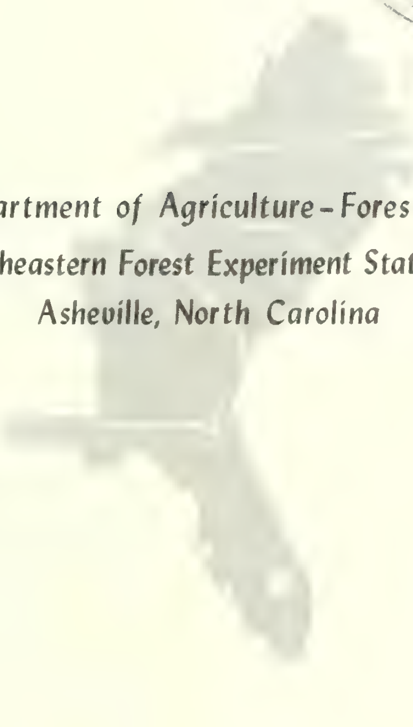

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Effect of Competition on Survival and Height Growth of Red Oak Seedlings

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Increasing acreages of hardwoods in the Southern Appalachians are being regenerated by methods which result in even-aged stands; and clearcutting is the method primarily employed. Research has shown that such harvest cuts almost invariably result in abundant reproduction.[1] [2] There is, however, little or no control of species composition in the resulting stands. Indications are that some species, although nominally adapted to conditions created by clearcutting, may require special measures to insure their inclusion in future stands. Northern red oak (*Quercus rubra* L.), one of our most valuable hardwoods, apparently is such a species.

In good seed years numerous red oak seedlings may become established under mature mixed-hardwood stands. Tryon and Carvell[3] counted up to 1,600 red oak stems per acre under oak stands in West Virginia. Several such good seed years may occur in the decade or so prior to final harvest of a stand.[4] The number of stems of red oak in succeeding sapling and pole-sized stands is often relatively small, however, compared to the number of seedlings that were established under the canopy in the years prior to harvest.

If red oak is to be a significant component of future even-aged hardwood stands, we must determine why seedlings fail to survive or develop through the seedling stage. Can seedlings survive for long periods under an overstory and still respond when released? Or, must the harvest cut be timed to take advantage of recent seedfall and newly established seedlings? What effect does low vegetation have on seedling survival and growth?

In 1963, a study was established to answer some of these questions. Objectives were to determine how well red oak seedlings survive and grow under an overstory, and how seedlings of different ages respond when released from the overstory or competition of lower vegetation or both. This paper presents results after six growing seasons.

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[1] McGee, Charles E. Regeneration in Southern Appalachian oak stands. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-72, 6 pp. 1967.

[2] Trimble, George R., and Hart, George E. An appraisal of early reproduction after cutting in Northern Appalachian hardwood stands. U. S. Forest Serv. Northeast. Forest Exp. Sta. Pap. 162, 22 pp. 1961.

[3] Tryon, E. H., and Carvell, K. L. Regeneration under oak stands. W. Va. Univ. Agr. Exp. Sta. Bull. 424 T, 22 pp. 1958.

[4] Beck, D. E., and Olson, David F., Jr. Seed production in Southern Appalachian oak stands. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Note SE-91, 7 pp. 1968.

Methods

Thirty-six plots were selected in well-stocked, mixed-hardwood stands on the Bent Creek Experimental Forest near Asheville, North Carolina. The presence of large, high-quality red oak trees was evidence that the sites were favorable for growth of this species. In each plot 10 or more newly established seedlings were selected and individually tagged in spring 1963. The selections were made in April and May during germination; an attached acorn demonstrated that the seedling was indeed newly established.

The plots were randomly assigned to a release treatment and time for treatment. Twelve plots were designated for treatment after the seedlings had completed one growing season, another 12 for treatment after two seasons, and the remaining 12 were designated for treatment after four growing seasons.

Within each year four treatment combinations were replicated three times: (1) control, (2) release from low vegetation, (3) release from overstory, and (4) release from both low vegetation and overstory. Release from low vegetation, both woody and herbaceous, was achieved by cutting all vegetation less than 4.5 feet tall in the immediate vicinity of each seedling. This treatment was first applied in the spring of the designated year and repeated annually as needed to maintain the plots. Release from the overstory was accomplished by cutting all trees greater than 4.5 feet tall to admit full light from overhead. The openings created in this manner varied from 1/5 to 1/4 acre in size.

To determine the effect of treatment, percentage survival and average total height of seedlings were subjected to analysis of variance at the end of six growing seasons. The treatment means were then compared to the controls by tests of least significant difference.[5] Effect of year of treatment was examined by analysis of variance of height growth during the first two seasons following release.

Results and Discussion

Survival

Seedling survival after six growing seasons varied greatly among individual plots —from 3 to 89 percent. However, survival was not significantly affected by either the level or timing of treatment. Survival was 54 percent for seedlings released from low vegetation, 39 percent for those released from overstory, and 43 percent for those released from both sources of competition, when averaged for the three times of release (table 1). None of these means for treated plots was significantly different from the control mean of 24 percent. Average survival for all 36 plots was a relatively low 38 percent.

Some of the seedlings died in each of the 6 years (fig. 1). However, the initially rapid rate of mortality slackened somewhat after the second year. Sixty percent of the total mortality occurred in the first 2 years.

The causes of mortality were not readily apparent in most cases but some could be attributed to insects and animals. In late spring of the first growing season, a number of seedlings were destroyed by rodents digging up the attached acorns. Some of the mortality during the first two growing seasons could be attributed to grubs or cutworms. The seedlings were cut beneath the

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[5] Steel, Robert G. D., and Torrie, James H. Principles and procedures of statistics, p. 106. New York: McGraw-Hill Book Co., Inc. 1960.

Table 1.—Northern red oak seedling survival after six growing seasons

Treatment	Survival when treated at age—		
	1 year	2 years	4 years
	Percent		
Control	24	20	24
Release from low vegetation	60	40	58
Release from overstory	33	36	61
Release from low vegetation and overstory	34	49	49

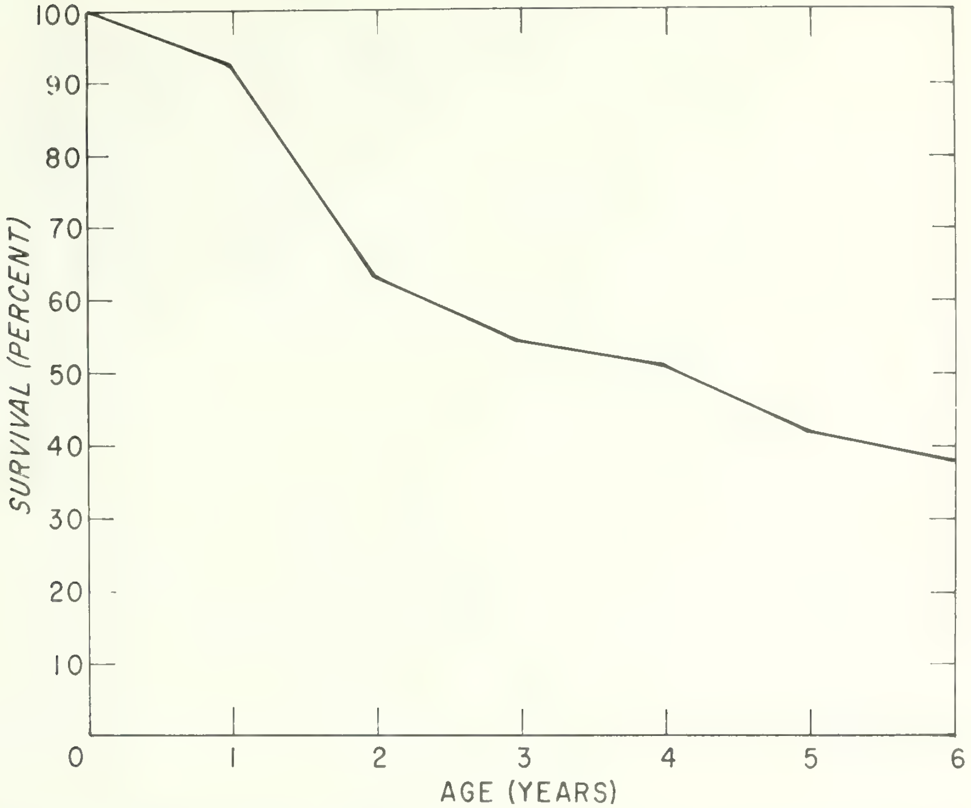

Figure 1.—Northern red oak seedling survival by number of years following establishment. Yearly averages are for all treatments combined.

litter layer but were otherwise intact. Almost all seedlings suffered some degree of defoliation by insects, but no mortality could be attributed to this cause. Numerous seedlings were browsed by deer, particularly on plots released from the overstory; but, here again, mortality from this cause could not be determined.

In the seasonal pattern of mortality, there was no indication of a particularly critical time or any one environmental factor contributing significantly to seedling loss. Approximately equal numbers of seedlings died in the dormant season as in the growing season. Of all seedlings which died over the 6 years, 46 percent died from April through September and 54 percent died from October through March.

Height Growth

Sixth-year height of seedlings varied with the level and timing of release (table 2). Average height of seedlings on the control plots was .48 foot. Seedlings released from only low vegetation at ages 1, 2, or 4 years were not significantly taller than the controls, averaging only .57 foot. Thus, the average height of seedlings grown under an overstory for 6 years was .54 foot. These same seedlings averaged .45 foot after the first season; there was practically no height growth for the next 5 years (fig. 2).

On the other hand, seedlings released from the overstory or from both the overstory and low vegetation were significantly taller than the controls. The magnitude of the difference depended on time of release. For example, seedlings released from the overstory at age 1 averaged 1.59 feet, compared to an average of .90 foot for those released from the overstory at age 4. This difference in response is attributed to the length of time elapsed since release rather than to an effect of age at time of release. That is, seedlings released at age 1 were taller because they had completed five seasons free from the overstory; those released at age 4 had grown only two seasons after release.

Table 2.—Height of northern red oak seedlings after six growing seasons

Treatment	Height when treated at age—		
	1 year	2 years	4 years
		Feet	
Control	0.51	0.57	0.47
Release from low vegetation	.51	.64	.55
Release from overstory	1.59	1.18	.90
Release from low vegetation and overstory	2.39	1.44	.93

While removal of low vegetation without removal of the overstory had no significant effect on height growth, there was a response to release from low vegetation once the overstory was removed. Unlike the immediate response to release from overstory, the added response to release from low vegetation was late to materialize. Seedlings released from both the overstory and low vegetation at age 1 were 50 percent taller five seasons later than were those seedlings released from only the overstory at age 1

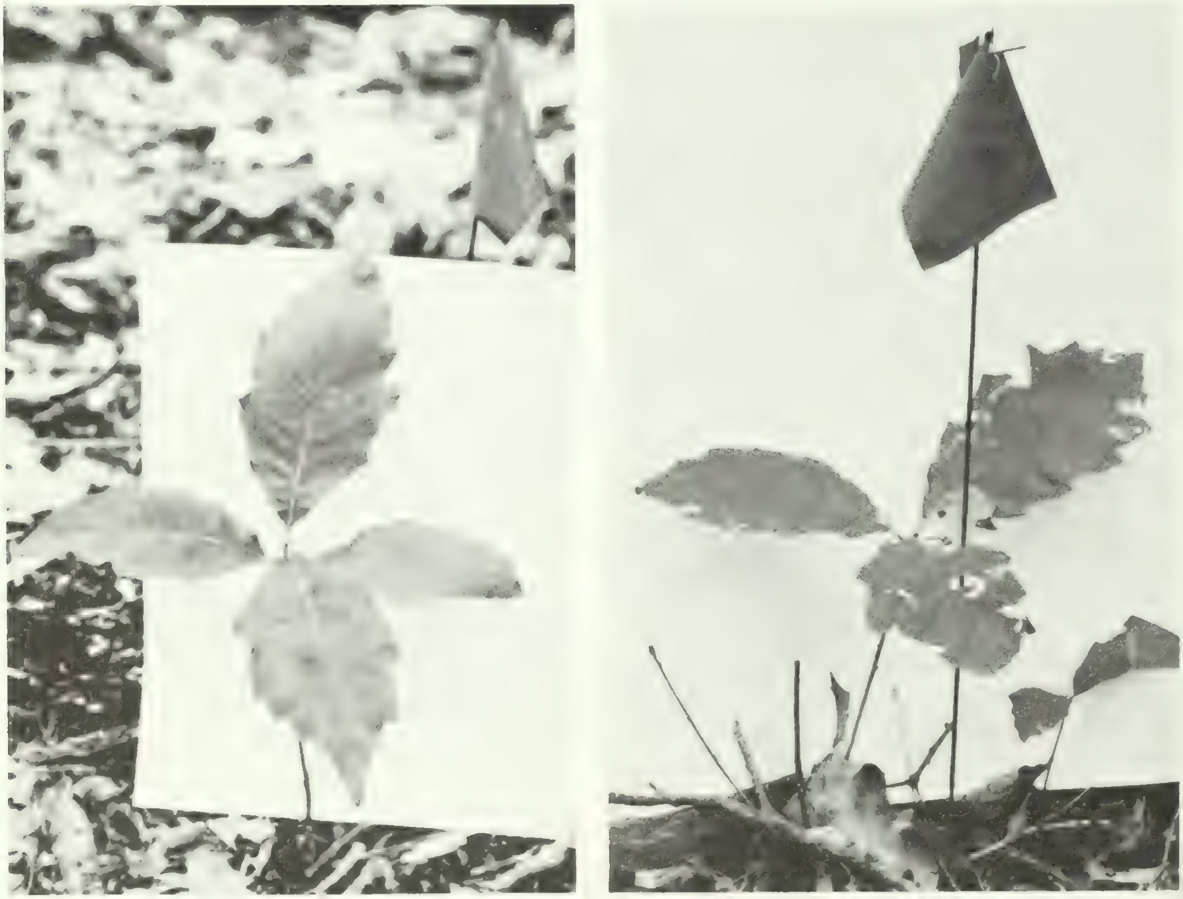

Figure 2.—Seedling at left is ½ foot tall after one growing season. The same seedling (right), after repeatedly dying back and resprouting under an overstory for six seasons, is still only ½ foot tall.

(table 2). However, an analysis four seasons after treatment showed no significant difference in the height of these seedlings. Likewise, the seedlings released from overstory and low vegetation at ages 2 or 4 years, having completed only four or two seasons after treatment, showed no advantage over those seedlings released from only the overstory at comparable ages. Thus, it appears that competition from the woody and herbaceous vegetation that springs up following overstory removal is not too severe the first few years. By the fifth season following overstory removal, however, seedlings and sprouts of other species had overtopped the red oak seedlings on those plots which received no release from low vegetation (fig. 3). Scholz and DeVriend[6] found that, under severe competition from shrubs and herbs, 81 percent of the red oak reproduction that followed clearcutting failed in 5 years. Thus, while the major effect on height growth in this study has been through overstory removal, release from low vegetation may become more important.

Effect of Age

The significant effect of time of release on sixth-year height was interpreted as a

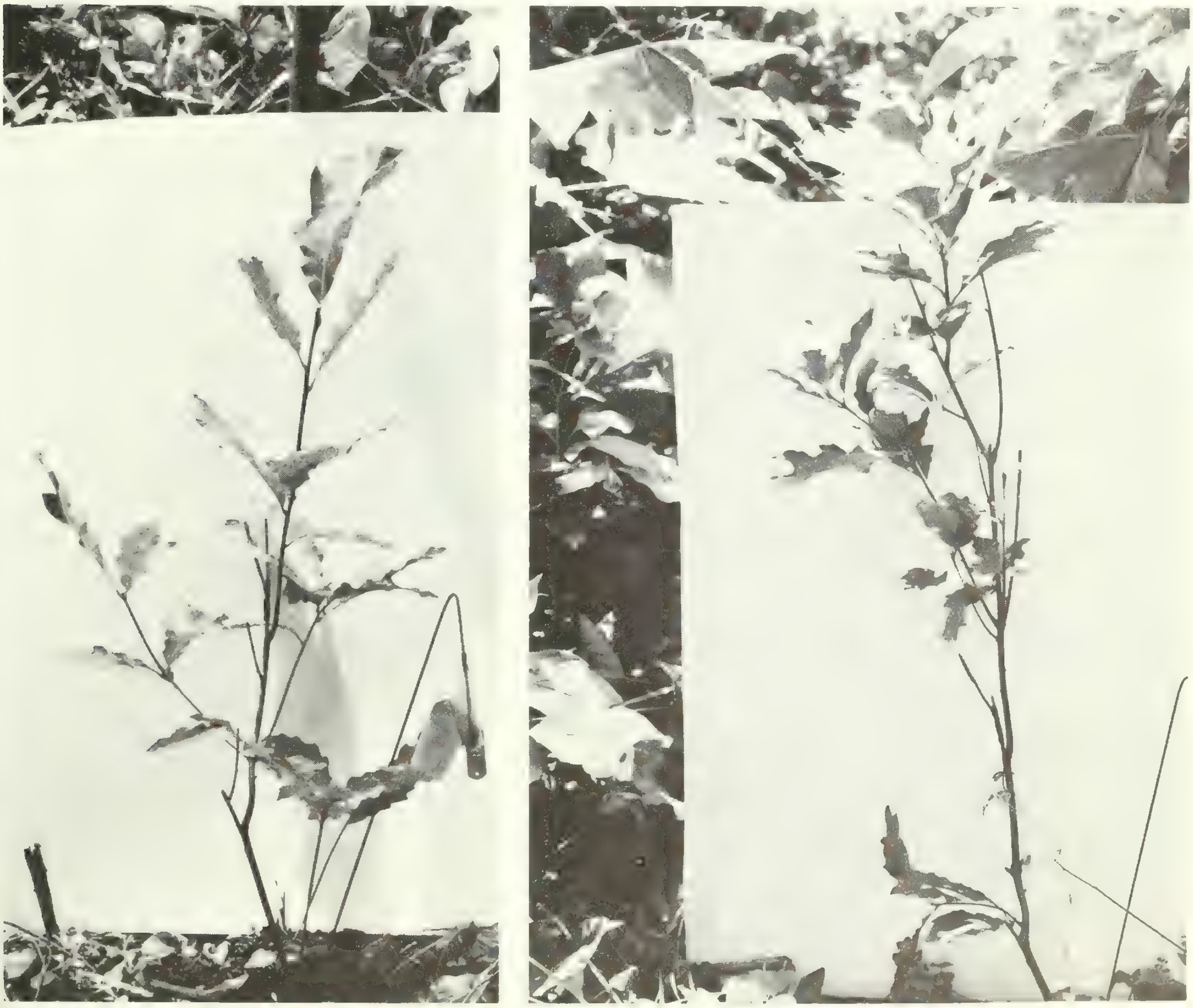

Figure 3.—Two seasons after the overstory was removed the red oak seedling (left) was free to grow. One year later the same seedling was 6 inches taller but was overtopped by dogwood sprouts and yellow-poplar seedlings.

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[6] Scholz, Harold F., and DeVriend, H. J. Natural regeneration on a 2-acre mixed oak clearcutting five years after logging. U. S. Forest Serv. Lake States Forest Exp. Sta. Pap. 48, 11 pp. 1957.

result of time elapsed since release rather than as a response to age or condition of the seedling at time of release. To determine if there was a difference in response associated with the age or condition of the seedling, height growth for the first two seasons following release was examined by analysis of variance. Because height was previously shown to be unaffected by release from low vegetation alone, analysis included only those seedlings released from the overstory, either alone or in conjunction with release from low vegetation. These data are summarized in table 3.

Age at time of release had no significant influence on growth immediately following release from the overstory. Average growth for the first two seasons following release was .34 foot for seedlings released at age 1, .36 foot at age 2, and .28 foot for seedlings released at age 4. Thus, the capacity of northern red oak seedlings to respond to release from the overstory was neither enhanced nor impaired by as long as 4 years under an overstory.

Summary and Conclusions

Survival of northern red oak seedlings after six growing seasons was unaffected by the release treatments imposed in this study. The seedlings survived no better when released from one or both sources of competition, than when under an overstory and in competition with low vegetation. The capacity of some seedlings to survive for relatively long periods under an overstory suggests the possibility of building up advance reproduction from several acorn crops prior to final harvest of the stand. The results also suggest that preharvest manipulation of the overstory—such as with a shelterwood system—may do little to enhance survival. The factors which influence survival in the early years do not appear to be closely related to condition of the vegetative competition, as evidenced by the extreme variation among plots treated identically in manipulation of the overstory and low vegetation. Some of the mortality was due to animals and insects which, no doubt, contributes to random pattern of mortality. Losses to rodents, for example, probably depend more on availability of other food than on condition of the overstory.

While seedlings were able to survive under an overstory, they did not grow appreciably until released. Seedlings which grew under the overstory for 6 years averaged only .54 foot; approximately 85 percent of this growth occurred in the first season. The greatest height attained by any seedling after six seasons under an overstory was 1.3 feet.

Seedlings released from the overstory after one, two, and four seasons responded with equal vigor. But as might be expected, the longer the time elapsed since release, the taller the seedling. On plots from which the overstory was removed, response to release from low vegetation was not statistically significant until the fifth year after release. Seedlings which had been released from only the overstory at age 1 grew as well for the first 4 years following release as those released from both overstory and low vegetation. In the fifth season, however, growth of seedlings receiving only overstory release was drastically curtailed. This finding suggests that the most opportune time, if any, for release from low vegetation would be 4 or 5 years after the overstory is removed; earlier release is apparently un-

Table 3.—Height-growth for two seasons immediately following treatment

Treatment	Height growth when treated at age—		
	1 year	2 years	4 years
	Feet		
Release from overstory	0.42	0.37	0.27
Release from low vegetation and overstory	.27	.34	.29
Average of all the replications	.34	.36	.28

needed. Release any later than the fifth year will result in reduced growth and possibly in loss of seedlings.

These findings indicate that northern red oak seedlings can survive for at least 6 years under an overstory. The study also shows an immediate response to release from the overstory and a belated response to concurrent release from low vegetation. None of these results assures us, however, that northern red oak will be a major component of future even-aged stands. The greatest height attained by any seedling 5 years after release from the overstory, with annual release from low vegetation, was only 5.1 feet. Considering that the seedling was .5 foot tall at the time of release, it averaged less than 1 foot growth per year after release. Only about one-third of the seedlings managed a growth rate of .5 foot per year after release. On good sites where yellow-poplar of seedling origin may grow better than 15 feet in 5 years following harvest by clearcutting, and sprouts grow even faster, red oak seedlings with their slow rate of growth are at a decided disadvantage. If red oak is to be a substantial component of even-aged stands following clearcutting, it will be necessary to develop special measures to speed its height growth or hold back its competitors.

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March 1970

FACTORS INFLUENCING STUMP SPROUTING OF SWAMP AND WATER TUPELO SEEDLINGS

by Donal D. Hook and Dean S. DeBell

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Factors Influencing Stump Sprouting of Swamp and Water Tupelo Seedlings

by

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Stump sprouting of water tupelo (*Nyssa aquatica* L.) and swamp tupelo (*Nyssa sylvatica* var. *biflora* (Walt.) Sarg.) is a major consideration in managing timber on swamp sites. Sprout growth is so rapid and profuse that both natural seedling reproduction and planted seedlings are usually overtopped. Control of stump sprouts with silvicides is possible, but costs are high because of difficulties in traversing swamps after logging. There are two logical choices: (1) accept the sprouts and manage for coppice reproduction, or (2) discourage sprouting through cutting practices and strive for seedling reproduction. Implementing either of these choices requires more detailed knowledge of the factors influencing sprouting of tupelos.

The effects of season of cutting and stored carbohydrates on sprouting of numerous species has been investigated (Aldous 1929; Stoeckeler 1947; Wenger 1953; and Kramer and Kozlowski 1960). However, no information is available for swamp species. The swamp habitat differs greatly from other hardwood sites, and Hook (1968) has shown that tupelos differ considerably from other species in some physiological and morphological characteristics. Therefore, it is logical to assume that the sprouting traits of tupelos may differ also from those of other hardwood species.

This report concerns the influence of time of cutting, stump height, starch content of stem and root, and ecotype on the incidence and growth of stump sprouts on swamp tupelo and water tupelo seedlings in a nursery bed.

EXPERIMENTAL CONDITIONS

Seedlings for this experiment were grown in two nursery beds at the Santee Experimental Forest, Berkeley County, South Carolina. The seed were originally collected from 15 sources of swamp tupelo and 14 sources of water tupelo representing a wide range of swamp conditions within a 100-mile arc of Charleston, South Carolina. Prior experiments with these seed sources had shown that germination and growth in the nursery bed and growth and morphology under artificially imposed water regimes varied by broad physiographic classifications of the swamp source (Hook and Stubbs 1967). These classifications were based on the physiographic position and drainage condition of the swamp. Because of distinct differences in phenotypic expression among physiographic sources, we now classify the physiographic seed sources used in this study as ecotypes.

METHODS

The preselected ecotypes of each species are given in table 1. Seedlings (1-0) from each source were transplanted in individual rows of eight seedlings each at 6- by 6-inch spacing 1 year prior to treatment. Cutting of the seedlings began on February 19, 1965, and continued at 3-week intervals through June 4, 1965. On each cutting date, one row of seedlings from one seed source of each ecotype was randomly chosen for cutting. One-half of the seedlings in each row were cut 6 inches above the soil (high) and one-half were cut ½ inch above the soil (low). The high and low cuts were randomly assigned to the north or south half of the row.

Table 1.—Number of seed sources per ecotype for each species

Ecotype	Number of seed sources	
	Water tupelo	Swamp tupelo
Red River Swamp (RR)	3	-
Black River Swamp (BR)	6	-
Non-alluvial Swamp (NA)	5	9
Pond Swamp (P)	-	6

Because there were insufficient numbers of seed sources per ecotype to cut the same source on every date, it was necessary to use different seed sources within the ecotype for each cutting date. This resulted in confounding within-ecotype variation with time of cut. Not all seedlings in the nursery bed were cut during the course of the experiment; hence, sprouts were interspersed and were competing with adjacent seedlings.

On each cutting date, we collected samples from the BR ecotype of water tupelo and the P ecotype of swamp tupelo for determining starch content of stem and root. A 1-inch-long section of the stem 6 inches above the soil surface and a 1-inch-long root section 1 inch below the root collar were collected from four uncut seedlings of each species. These sections, approximately ½ to 1 inch in diameter, were ovendried 24 hours at 70° C., ground to pass through a 60-mesh screen, and stored in a desiccator. Samples (combined bark and xylem) were analyzed for starch content by the technique described by McCready et al. (1950).

The number of sprouts, average height, and position of sprouts on the stump were recorded 6 weeks after cutting. At the end of the first growing season, each sprout was measured for height, diameter at 1 inch above point of origin, and distance above root collar to point of origin. Within each species, six stumps from each height class were sectioned and examined under a binocular microscope to determine if sprouts had developed from adventitious or suppressed buds.

ANALYSIS

Production of stump sprouts was analyzed in terms of the number of sprouts per stump 6 weeks after cutting and at the end of the growing season. Also, total length of sprouts per stump and cubic volume index of the tallest sprout per stump were analyzed at the end of the growing season. The expression D^2H (where D represents sprout diameter 1 inch above point of origin and H represents sprout height) was used as an index of cubic volume. Both variables were measured in inches.

Variation due to border effects, i.e., differences in light and competition from the outside to the inside of the nursery bed, was accounted for by the introduction of a position variable. The study was analyzed separately by species, with water tupelo in a 6 x 3 x 2 factorial arrangement and swamp tupelo in a 6 x 2 x 2 factorial arrangement applied to a randomized block design. Six cutting times (T), three and two ecotypes (E), respectively, and two stump heights (S) were the factors tested. Because within-ecotype variation was confounded with time of cut, the interactions of T x E and T x E x S were combined with the error term.

RESULTS AND DISCUSSION

Water Tupelo

Sprouting 6 weeks after cutting was related to stump height (S) and time of cut (T) but not to ecotype (E) (table 2). Few sprouts developed on low stumps until a callus ring formed around the periphery of the stump surface—this generally took more than 6 weeks.

Number of sprouts per stump at the end of the growing season was significantly re-

Table 2.—Average number of sprouts per stump on water tupelo 6 weeks after cutting

Stump height	Cutting date					
	2/19	3/12	4/2	4/23	5/14	6/4
High	3.5	3.0	5.7	6.2	5.1	4.6
Low	0	0	0	0	0.2	0.6

lated to T, T x S, and S x E. Low stumps had more sprouts than did high stumps for the first three cutting dates but had fewer sprouts on the last three cutting dates. The number of sprouts on high stumps was not affected as much by cutting date as was the number on low stumps (fig. 1a). The RR ecotype had fewer sprouts on high stumps than did the BR and NA ecotypes but had more sprouts on the low stumps than did the BR and NA ecotypes (fig. 1b).

Total length of sprouts per stump was significantly related to E, T, T x S, and E x S. On the first two cutting dates, low stumps had a greater total length of sprouts than did high stumps. However, total length of sprouts on low stumps decreased rapidly after the second cutting, but total length of sprouts on high stumps decreased only slightly during this period (fig. 2a). The RR ecotype had less total length of sprouts on both high and low stumps than did the BR and NA ecotypes. Variation in total sprout length by ecotype was less among low stumps than among high stumps (fig. 2b).

Cubic volume index was related to E, S, and T. Its relationship to T is shown in figure 3a and to E and S in figure 3b. The

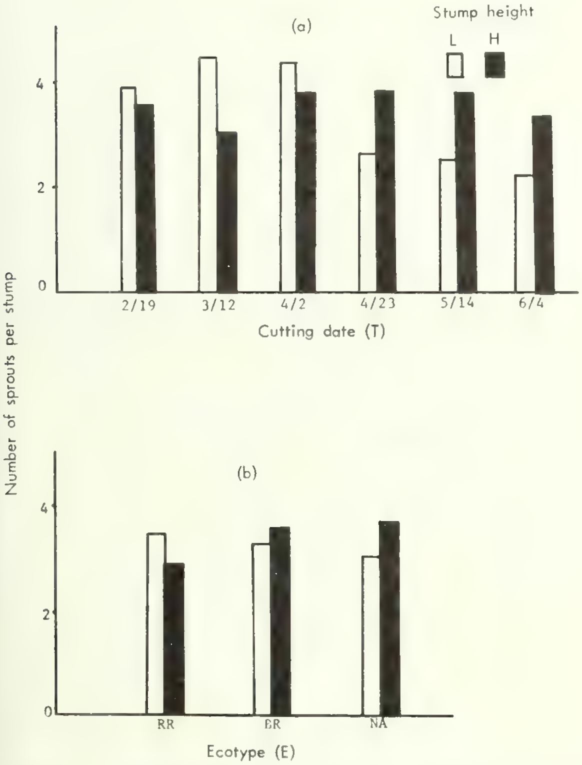

Figure 1.—Number of sprouts per stump at end of growing season by cutting date (a) and ecotype (b) for high and low stumps of water tupelo.

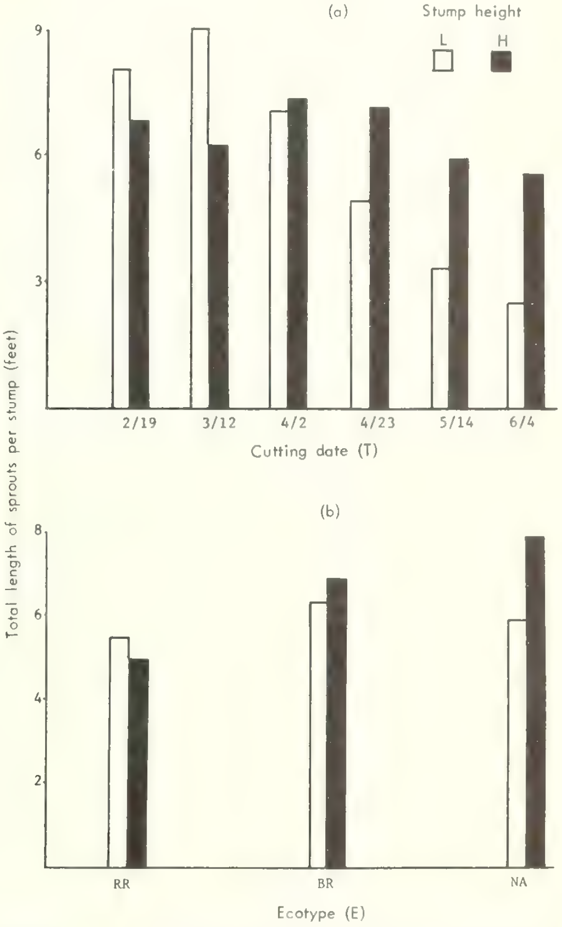

Figure 2.—Total length of sprouts per stump 6 weeks after cutting by cutting date (a) and ecotype (b) for high and low stumps of water tupelo.

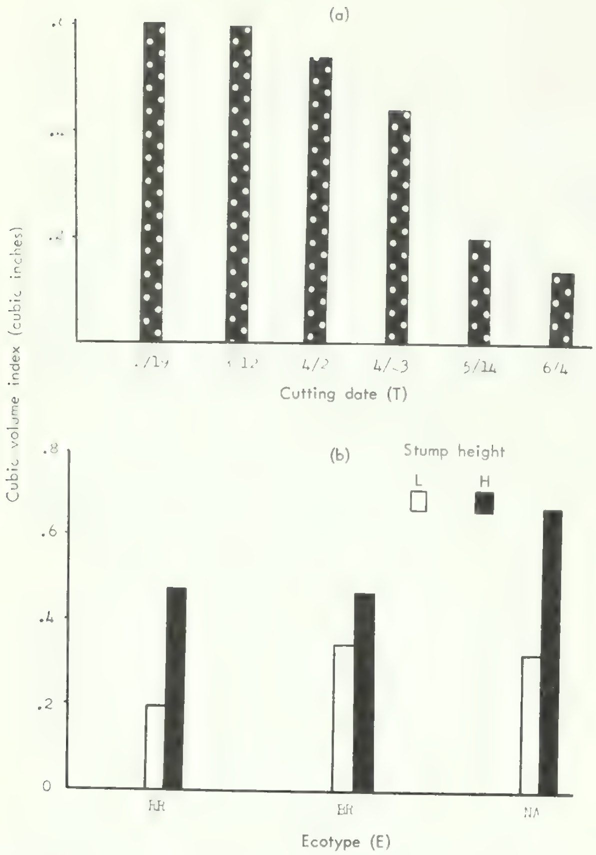

Figure 3.—(a) Cubic volume index of the tallest sprout per stump in relation to cutting date (T) for all stump heights of water tupelo. (b) Cubic volume index of the tallest sprout per stump in relation to ecotype (E) for high and low stumps of water tupelo.

growth of dominant sprouts (cubic volume index) decreased more rapidly with time of cut than did number and total length of sprouts. This rapid decline in cubic volume index probably reflects the influence of growing time on height growth of dominant sprouts (diameter usually 1 inch or less), since the expression D^2H is most sensitive to height changes when D is small. Sprouts which originated highest on the stumps were also the tallest and most vigorous sprouts on 82 percent of the stumps sampled.

Sprout origin varied by stump height. Of the 24 sprouts examined on the six high stumps, all arose from suppressed buds, i.e., their pith could be traced to seedling pith. But on the six low stumps, five sprouts arose from suppressed buds, 10 sprouts arose from adventitious buds, and three sprouts could not be traced because of decay.

Changes in starch content during the course of six consecutive cuts were more pronounced in root sections than in stem sections (table 3). Root sections had a high concentration of starch at the time of the first two cuttings, dropped markedly on the third and fourth cuts, but increased sharply by the fifth cut. In contrast, the stem sections showed no appreciable change in starch content through the third cut (early April) but showed slight increases on the fourth and the sixth cutting date.

Stump height influenced sprouting of water tupelo through its effect on the manner of sprout origin and the amount of starch available at the time of cutting. A majority of the sprouts on low stumps were of adventitious origin and did not begin their development until 6 weeks or more after seedlings were cut. In contrast, sprouts on high stumps originated from suppressed buds and developed within 6 weeks after cutting.

Table 3.—Starch content of stem and root sections of water tupelo and swamp tupelo by cutting date

Species and section	Cutting date					
	2/19	3/12	4/2	4/23	5/14	6/4
	Percent[1] [2]					
Water tupelo (BR)						
Stem	2.6	2.3	1.1	3.1	3.0	4.6
Root	11.2	10.9	3.4	1.1	9.5	13.0
Swamp tupelo (P)						
Stem	1.4	1.5	2.5	1.0	1.1	4.2
Root	9.9	9.9	11.2	0.2	5.1	9.3

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[1] Starch values are expressed as percent of ovendry weight.

[2] Values not connected by a common line were significantly different at the .05 level.

The number and total length of sprouts on each high stump varied little during the 18-week cutting period (figures 1a and 2a). However, low stumps cut early in the season had a greater number and total length of sprouts than did high stumps, but total length of sprouts on low stumps declined rapidly during the last three cutting dates. High stumps showed only a relatively small decline in number and total length of sprouts for the same period.

This pattern suggests that not only growing season remaining after each cut but also starch content of the roots at the time of cut were factors involved in determining the number and total length of sprouts per stump. If the growing time after cutting were the controlling factor, one would expect sprouts of both high and low stumps to have the same response pattern for each cutting date. However, their response patterns differed, as pointed out above; and number of sprouts on low stumps of the BR ecotype was closely correlated to variation in starch content of roots by cutting date (fig. 4). Although starch content was sampled only for the BR ecotype, the RR ecotype showed a similar correlation between number of sprouts on low stumps and starch content of roots of the BR ecotype. In contrast to the pattern

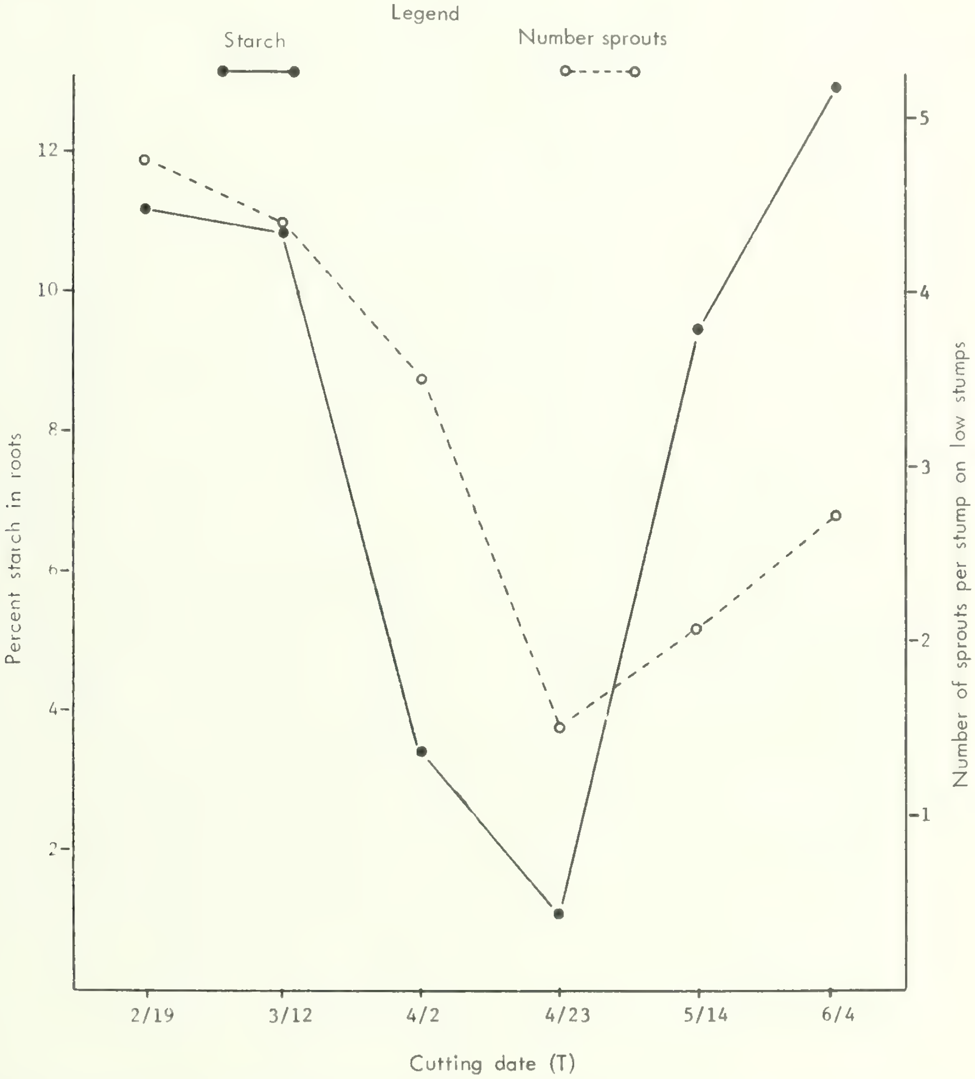

Figure 4.—Starch content of root and number of sprouts by cutting date for the BR ecotype of water tupelo.

displayed by the BR and RR ecotypes, no sprouts developed on the NA ecotype after May 14.

The interaction of ecotype with stump height (E x S) shows the difference in sprouting potential among the three ecotypes (figures 1b and 2b). Ecotypes BR and NA had a greater number and total length of sprouts on high stumps than did the RR ecotype. We feel that differences in starch content among ecotypes and the distribution of suppressed buds could account for ecotypic differences.

Swamp Tupelo

Sprouting 6 weeks after cutting was significantly related to T, S, E, and T x S. Number of sprouts on high stumps peaked on the third cutting date and declined thereafter. High stumps had more than three times as many sprouts as low stumps, and the NA ecotype had more sprouts than the P ecotype. Also, the difference between the number of sprouts on high and low stumps differed with T. Number of sprouts on high stumps increased through the third cutting date and then declined. In contrast, there were no significant differences in number of sprouts on low stumps with cutting date (fig. 5a).

The number of sprouts per stump at the end of the growing season was related only to stump height; high stumps averaged 5.3 and low stumps averaged 2.2 sprouts per stump. Total length of sprouts per stump was significantly related to T and S. Stumps cut during the first three cutting dates had a greater total length of sprouts than did those cut during the last three cutting dates, and high stumps had a greater total length of sprouts than did low stumps. Cubic volume index of the tallest sprout per stump was related only to T; volume decreased rapidly after the first two cutting dates (fig. 5b). Also, the sprouts which originated highest on the stump were the tallest and most vigorous sprouts on 85 percent of the stumps.

Of the 12 seedlings randomly chosen to trace sprout origin, three had no sprouts, one was dead, but the remaining eight seedlings had a total of 34 sprouts. We were able to trace the pith of all of these sprouts back to seedling pith; hence, all 34 sprouts had developed from suppressed buds.

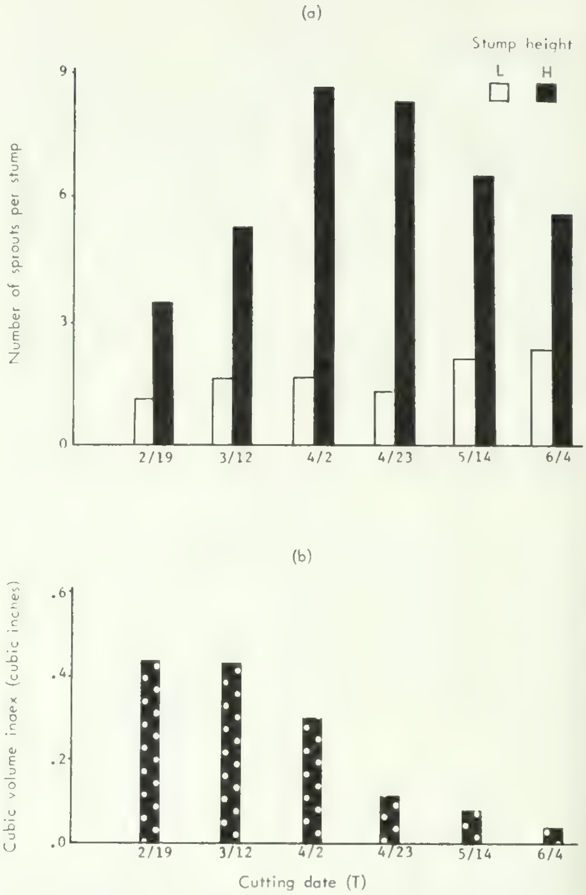

Figure 5.—(a) Number of sprouts per stump 6 weeks after cutting by stump height and cutting date for swamp tupelo. (b) Cubic volume index of the tallest sprout per stump by cutting date for all stump heights.

Starch content of swamp tupelo stem and root sections varied by cutting date in essentially the same manner as did that of water tupelo sections (table 3). Root sections had a much higher concentration of starch—about 10 percent at its peak compared to about a 4.0-percent peak in stem sections. Also, the root sections showed a marked decrease in starch content in late April with a subsequent sharp rise in concentration in May and June. The level of starch in the stem sections was relatively constant with small peak concentrations on April 2 and June 4.

The smallest number of sprouts per stump on low stumps occurred at the time starch content of root was lowest for the P ecotype (fig. 6). However, the NA ecotype showed little change in number of sprouts by cutting date.

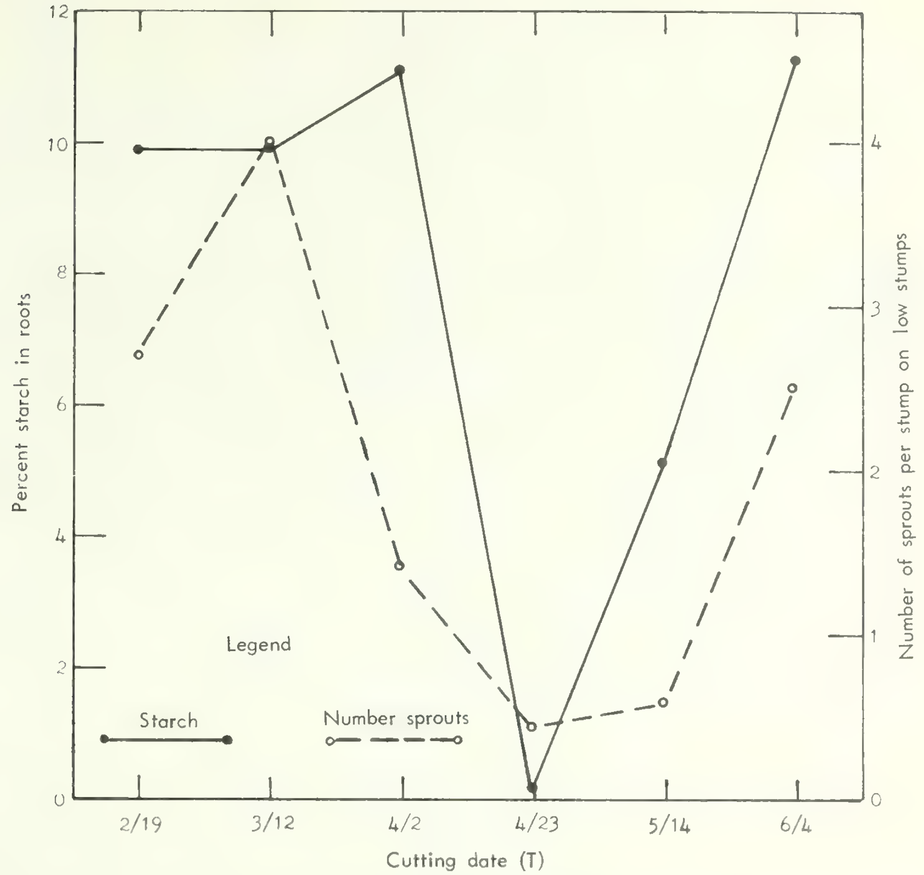

Figure 6.—Starch content of root and number of sprouts by cutting date for the P ecotype of swamp tupelo.

General

The major difference in sprouting response between these two species was in initial sprouting on low stumps. Water tupelo did not sprout for 6 weeks after cutting except on the last two cutting dates, but swamp tupelo sprouted prolifically within this time period on all cutting dates. Differences in time of sprout initiation were closely correlated with origin of sprouts. A large percentage of the sprouts on low stumps of water tupelo arose adventitiously, while sprouts on swamp tupelo arose from suppressed buds. Part of this variation in origin of sprouts can be attributed to differences in length of hypocotyl of the two species. Water tupelo seed are several times larger than swamp tupelo seed and consequently produce hypocotyls 2 to 5 inches tall, whereas the hypocotyls on swamp tupelo are 1 to 3 inches tall (fig. 7).

Because the seedlings in the nursery beds had been replanted at age 1, it is probable that a high percentage of the seedlings were planted with the root collar well below ground level. If this were the case, cutting stems 1/2 inch above ground level would have resulted in cutting more water tupelo stems below the cotyledons (within hypocotyls) than swamp tupelo because of the inherently shorter hypocotyl on the latter. Buds originating below the cotyledons would be adventitious in origin because this section of the stem is not an internode and by definition does not contain suppressed bud structures (Esau 1965).

The small seasonal changes in starch content of the stem of these young seedlings (2+ years old) are comparable with carbohydrate changes reported for other woody species (Wenger 1953; Kramer and Kozlowski 1960). However, the sharp drop in starch content in the roots during April and the rapid recovery within 6 weeks deviate considerably from total carbohydrates reported for sweetgum. Wenger reported a sharp decline in carbohydrates (sugar) in roots of

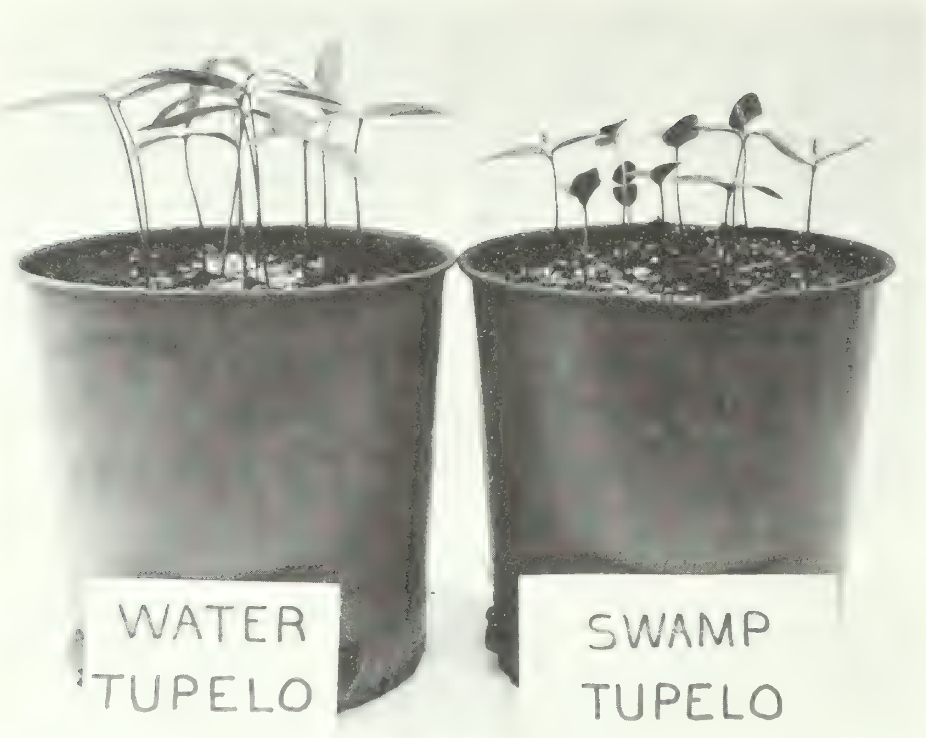

Figure 7.—Water tupelo and swamp tupelo seedlings in the cotyledon stage—about 5 days after germination.

sweetgum in late March, but recovery of carbohydrates was not complete until early August. Further, Wenger found that seasonal growth of sprouts was poorly correlated with carbohydrate content of stem and roots. This poor correlation is consistent with our observations on high stumps. However, sprouting response on low stumps of tupelos shows that incidence of sprouting is correlated to a low starch content in the roots in the absence of any appreciable amount of stem wood. This correlation is expressed regardless of origin of sprouts. Theoretically, low starch content should be more critical on low stumps of water tupelo because sprouts are delayed until a callus ring is formed on the stump. During this period all growth activity is dependent upon root reserves (which are essentially zero in late April) and the amount of reserves in the short stem section. However, there were no large differences in species response in this relationship.

Ecotype was more important to sprouting response in water tupelo than in swamp tupelo. This difference suggests that there is more genetic variation in sprouting response among physiographic sites in water tupelo than in swamp tupelo. Both species are insect pollinated; but swamp tupelo seeds are distributed by birds (DeBell and Auld 1968) and gravity (DeBell and Hook 1969), while water tupelo seeds are distributed by water and gravity only. Consequently, distribution of water tupelo seed is essentially unidirectional (downstream), while that of swamp tupelo is multidirectional. These factors, plus possible differences in flowering time among physiographic sites, may place further restrictions on gene flow even over short distances of a few miles.

Cutting stumps low (1/2 inch above soil) at the time of lowest root reserves hampered total sprout production of both species. Cuts later in the season also restricted cubic volume (D^2H) growth of the tallest sprout per stump. High stumps cut earlier in the season favored total sprout production. Apparently, the beneficial effects of cutting stumps high can be attributed to sprout origin and reserve carbohydrate content.

Sprouts on high stumps originate from suppressed buds and erupt sooner than those from adventitious buds. Carbohydrate content of the stem fluctuates less than root reserves and never reaches as low a level as the reserves in the root; hence, more carbohydrate reserves are theoretically available for growth in high stumps.

Sprouts that originated highest on the high stumps were the dominant sprouts on more than 80 percent of the stumps. Hence, vertical position of the sprout on the parent stump is a major factor in determining the dominance of sprouts. Dominance of the highest vertically positioned sprout might be attributed to superior elevation per se, or highest buds may erupt first and assert dominance in this manner. In either case, they maintain dominance at least through the first growing season.

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YIELD OF UNTHINNED YELLOW-POPLAR

MAY 27 1970

by
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Forest Service
U. S. Department of Agriculture

Unthinned Yellow-Poplar

by

ck and Lino Della-Bianca, Silviculturists

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determined. Bennett and Clutter[1] have demonstrated the utility of such information for solution of problems on multiple-product yield.

METHODS

Plot Selection

Data for this study were obtained from 141 circular ¼-acre plots established in the Appalachian Mountains of North Carolina (93 plots), Virginia (31 plots), and Georgia (17 plots). Stan ge, site index,
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p. 1968.

1970. Yield of Unthinned Yellow-Poplar. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-58, 20 pp.

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Yield of Unthinned Yellow-Poplar

by

Donald E. Beck and Lino Della-Bianca, Silviculturists

Decisions about timber management, whether they be made by a small landowner using simple arithmetic or by a corporate forester with the aid of economic investment theory, advanced mathematical techniques, and digital computers, require a basic tool—a list of timber products that can be expected at various ages, that is, a yield table. This paper presents yields from natural unthinned stands of yellow-poplar (*Liriodendron tulipifera* L.) at various ages by site index and density class. It also brings together under one cover some of the previously developed mensurational tools needed to bring this high-value timber species under management.

The yield estimates were developed by an analysis of diameter distribution. With this technique, (1) numbers of trees are estimated by diameter class from measurements of age, site index, and stand density, (2) heights of trees of given diameters are estimated from the same independent variables, (3) volume of a tree of a given height and diameter is determined from tree-volume equations, and (4) the volumes are applied to the diameter distribution to obtain per-acre yields. The advantage of this method is that distribution of size classes as well as total volume per acre can be determined. Bennett and Clutter[1] have demonstrated the utility of such information for solution of problems on multiple-product yield.

METHODS

Plot Selection

Data for this study were obtained from 141 circular $\frac{1}{4}$-acre plots established in the Appalachian Mountains of North Carolina (93 plots), Virginia (31 plots), and Georgia (17 plots). Stand age, site index, and diameters of all trees ≥ 4.5 inches d.b.h. were determined on each plot. Total height was determined from a random sample of trees in each diameter class.

To be included in the study, a stand had to have 75 percent or more of its overstory, by number of trees, in yellow-poplar. All the stands were even-aged and ranged from 17 to 76 years of age. Site index (fig. 3, Appendix) at age 50 ranged from 75 to 140 feet, and basal area varied from 44 to 208 square feet per acre. The largest and smallest numbers of trees per acre encountered in each age and site index class are shown in table 1.

Sampled stands were free of disease and insect damage and showed no evidence of past cutting. In each of the plots, the trees were well distributed.

Cover photo: A yellow-poplar stand near Wolf Ford, Pisgah National Forest. This 40-year-old stand, growing on site 130 land, has 300 trees per acre, and contains nearly 30,000 board feet of sawtimber per acre. The abandoned railroad trestle in the foreground was erected and used by the Carr Lumber Company in logging the area in the 1920's.

[1] Bennett, F. A., and Clutter, J. L. Multiple-product yield estimates for unthinned slash pine plantations—pulpwood, sawtimber, gum. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-35, 21 pp. 1968.

Table 1.—Largest and smallest numbers of trees per acre by age and site index classes[1]

Site index (Feet at age 50)	Age (years)						
	< 21	21-30	31-40	41-50	51-60	61-70	> 70
< 81	---- ----	---- ----	---- ----	220 220	---- ----	---- ----	---- ----
81-90	---- ----	228 228	240 320	---- ----	140 168	72 196	---- ----
91-100	---- ----	160 380	256 256	100 172	96 208	72 232	68 140
101-110	---- ----	176 364	136 252	48 272	84 272	100 192	---- ----
111-120	---- ----	152 252	152 332	136 212	132 156	88 176	---- ----
121-130	216 216	236 396	124 256	96 188	152 152	136 136	---- ----
131-140	---- ----	164 328	140 204	---- ----	---- ----	---- ----	---- ----
> 140	184 184	---- ----	---- ----	---- ----	---- ----	---- ----	---- ----

[1] Only trees 4.5 inches d.b.h. and larger are included.

Diameter Distribution

Diameter distributions based on the 141 sample stands were developed earlier by McGee and Della-Bianca[2] following procedures developed by Clutter and Bennett.[3] The expected number of trees per acre by 1-inch diameter classes was calculated for various combinations of age, site index, and stand density. For convenience, these values are presented in tables 8 through 12 in the Appendix.

Height-Diameter Relationships

Before the volumes for individual trees could be determined, it was necessary to compute the heights of trees in given diameter classes. These heights were derived with the following model:[4]

$$\begin{aligned}[\mathrm{Log}\ (H_C) - \mathrm{Log}\ (H)] &= b_0 + b_1\ (1/D - 1/D\max) \\ &+ b_2\ (\mathrm{Log}\ T)\ (1/D - 1/D\max) \\ &+ b_3\ (1/A)\ (1/D - 1/D\max) \\ &+ b_4\ (S)\ (1/D - 1/D\max) \qquad (1)\end{aligned}$$

where

Log = common logarithm
H_C = average height of dominant and codominant trees in feet
H = total height in feet of a tree of diameter D in inches
Dmax = maximum diameter occurring in the stand
T = number of trees per acre
A = age of stand in years
S = site index

Maximum diameter is predicted by the equation[5]

$$\begin{aligned}D\max = &\ 9.38123 \\ &+ 2.41398\ (A \times S/1000) \\ &- 0.35928\ (A \times T/1000) \qquad (2)\end{aligned}$$

Coefficients of the above height model were estimated from the least-squares fit of the model to data from 1,782 sample trees. After simplifying and decoding, the equation for estimating the height of a tree of given diameter is

$$\begin{aligned}\mathrm{Log}\ (H) = &\ \mathrm{Log}\ (H_C) + 0.01857 \\ &- [2.28645 - 0.59146\ \mathrm{Log}\ (T) \\ &- 0.64614\ (100/A) \\ &+ 2.57302\ (S/100)] \\ &\quad (1/D - 1/D\max) \qquad (3)\end{aligned}$$

Several features of this height model merit special attention. First, the mode of expressing the variables insures that estimated height of the largest trees will closely approximate measured height of the dominant and codominant trees used in estimation of site index; when $D = Dmax$, $Log(H)$ is equal to $Log(H_c)$ plus a small constant. Secondly, note that for a given stand, values of $Log(H_c)$, T, A, S, and Dmax are constants, so that the equation simplifies to

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[2] McGee, C. E., and Della-Bianca, Lino. Diameter distributions in natural yellow-poplar stands. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-25, 7 pp. 1967.

[3] Clutter, J. L., and Bennett, F. A. Diameter distributions in old-field slash pine plantations. Ga. Forest Res. Counc. Rep. 13, 9 pp. 1965.

[4] This model was developed by Dr. Jerome L. Clutter, Union-Camp Associate Professor of Forestry, University of Georgia, Athens.

[5] See footnote 2.

$$Log(H) = b_0' + b_1' (1/D) \qquad (4)$$

Tables 13 through 17 in the Appendix show estimated heights by diameter classes for selected combinations of age, site index, and stand density.

YIELD ESTIMATES

Volumes for individual trees of a specified diameter and estimated height from equation 3 were determined from the tree-volume equations developed by Beck:[6] [7]

Total cubic-foot volume of wood and bark $= 0.0025 (D^2 H) - 0.0028$ (5)

Cubic-foot volume of wood and bark to a 4-inch top, outside bark $= 0.0024 (D^2 H) - 0.6417$ (6)

Cubic-foot volume of wood only to a 4-inch top, outside bark $= 0.0020 (D^2 H) - 0.6837$ (7)

International ¼-inch board-foot volume $= 0.0148 (D^2 H) + 0.0203 (D^3) - 0.5982 (D^2) - 44.8597 (D/H) + 1321.0515 (1/H) - 32.6851$ (8)

These volumes for individual trees were then applied to the number of trees in each diameter class for a given combination of age, site index, and stand density (tables 8 through 12) to produce the yield estimates in tables 2 through 5.

There were no readily available statistics, such as the coefficient of determination or standard error of the estimate, that we could use to evaluate the reliability of these yield estimates directly. Therefore, the estimated yields for the 141 sample plots were compared to actual yields and summarized in table 6.

As a further check on the reliability of the method, yields were estimated for an independent sample of six stands and the results compared to actual yield (table 7).

DISCUSSION

Cubic-Foot Estimates

The average differences between actual and estimated cubic-foot volumes (i.e., the sum of signed deviations of estimated volume from actual volume divided by number of plots) of the 141 sample plots were very nearly zero (table 6). Examination of the differences in relation to age, site index, and density indicates that the diameter-distribution method gives unbiased estimates of total and merchantable cubic-foot volume per acre. The standard deviation of differences for total cubic-foot volume in table 6 shows that one can expect approximately 68 percent of the estimates to be within 1,010 cubic feet of actual volume, but that 28 percent of these estimates will be in error by 1,010 to 2,020 cubic feet per acre.

The reliability of cubic-foot estimates was corroborated by application to the independent sample of stands (table 7). Estimated average volume was very close to actual volume, and two-thirds of the errors were less than 1,010 cubic feet.

Total and merchantable cubic-foot yields increased with increasing age, site index, and density level. There was no culmination of cubic-foot yield within the range of densities sampled. The greater the number of trees, the larger the yield at all ages and levels of site index. However, for a given age and site index, each additional tree added did not add equal amounts to yield (fig. 1). This was particularly true as stand age increased. For example, when the number of trees at age 60 on site index 100 is increased from 100 to 150 per acre, total cubic-foot volume is increased by 810 cubic feet per acre; but, when the number is increased by another 50 trees (from 150 to 200 trees per acre), total volume is increased by only 460 cubic feet per acre. As more trees are added, increasing numbers fall into the smaller diameter classes and the number of trees in the larger diameter classes is reduced (tables 8 through 12).

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[6] Beck, D. E. Cubic-foot volume tables for yellow-poplar in the southern Appalachians. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-16, 4 pp. 1963.

[7] Beck, D. E. International ¼-inch board-foot volumes and board-foot/cubic-foot ratios for Southern Appalachian yellow-poplar. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-27, 4 pp. 1964.

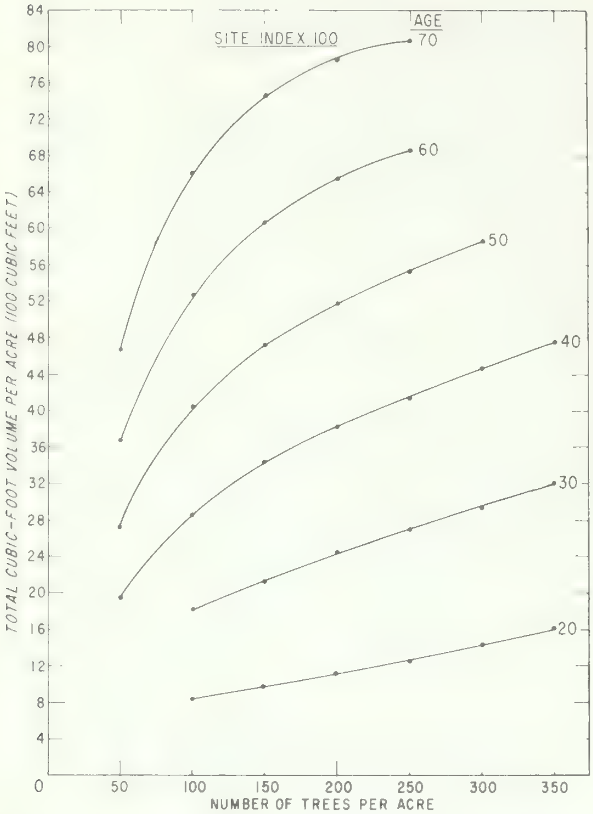

Figure 1.—Total cubic-foot volume per acre increases with number of trees. In older stands the rate of increase declines sharply after the first 100 trees per acre.

Board-Foot Estimates

Estimates of board-foot volume were not as precise as those for cubic-foot volume. The coefficient of variation for board-foot volume was 31 as compared to 20 for total cubic-foot volume. However, the difference between the averages for actual and estimated board-foot volume was small, and there was no evidence of bias (table 6).

Again, application of the estimating procedure for board-foot volume to the independent sample (table 7) shows the expected degree of precision. Estimated average volume closely approximates average actual volume; two-thirds of the individual estimates are in error by less than 5,380 board-feet per acre.

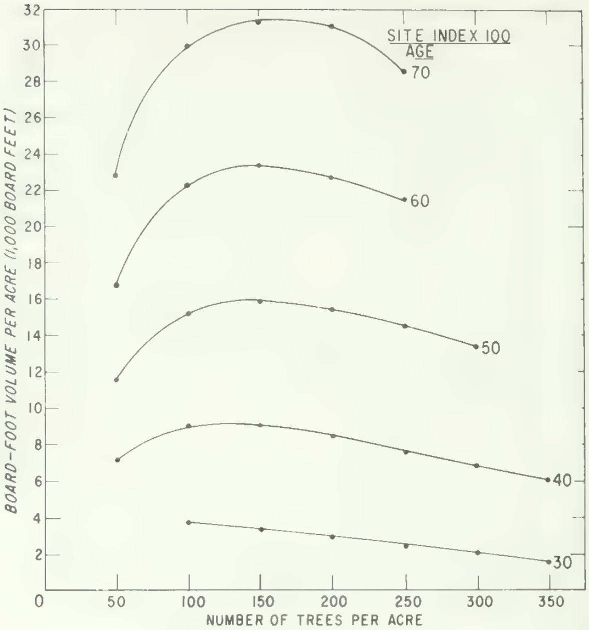

Figure 2.—For certain combinations of age and site index, board-foot yield culminates with increasing stand density.

Unlike the cubic-foot yields, board-foot yield culminated with increasing numbers of trees for certain combinations of age and site index (fig. 2). Increasing the number of trees from 100 to 150 per acre on site index 100 at age 60 increased sawtimber volume by 1,100 board feet per acre, but an additional 50 trees (200 per acre) resulted in a decrease of 600 board-feet per acre. In this case, the decrease in average tree size associated with increasing numbers of trees resulted in an actual loss of merchantable volume.

APPLICATION OF YIELD ESTIMATES

The diameter distributions, height-diameter relationships, and volume yields presented here are representative of the natural development of unthinned yellow-poplar stands. It should be recognized that managed stands of the future will be thinned and will not have diameter distributions and volume yields identical to those for the stands reported here.

It is important to note that the tables do not describe changes with time on a given site. To determine yields, it must be assumed that a given number of trees will be present at a specified time. This, however, should not impose undue restriction on use of the tables. Within the range of ages and densities sampled, the change in numbers of trees larger than 4.5 inches d.b.h.

(Text concluded on page 9)

Table 2.—Total cubic-foot yield of wood and bark for unthinned yellow-poplar stands of various stand densities, site indices, and ages[1]

Trees per acre (number)	Age (years)					
	20	30	40	50	60	70
	Cubic feet per acre					
SITE INDEX 90						
50	----	----	1,560	2,170	2,850	3,590
100	730	1,510	2,330	3,180	4,080	5,020
150	860	1,810	2,760	3,710	4,660	5,580
200	980	2,020	3,050	4,030	4,950	5,780
250	1,110	2,210	3,280	4,260	5,130	5,870
300	1,250	2,400	3,490	4,450	----	----
350	1,410	2,600	3,710	----	----	----
SITE INDEX 100						
50	----	----	1,920	2,730	3,640	4,670
100	840	1,810	2,870	4,020	5,270	6,610
150	990	2,180	3,430	4,730	6,080	7,450
200	1,120	2,450	3,820	5,180	6,540	7,840
250	1,270	2,700	4,140	5,540	6,870	8,090
300	1,430	2,950	4,460	5,870	----	----
350	1,620	3,220	4,770	----	----	----
SITE INDEX 110						
50	----	----	2,340	3,380	4,600	5,990
100	960	2,150	3,500	5,020	6,720	8,600
150	1,130	2,600	4,210	5,960	7,840	9,830
200	1,280	2,940	4,740	6,610	8,550	10,540
250	1,450	3,270	5,200	7,160	9,130	11,060
300	1,650	3,610	5,650	7,670	----	----
350	1,870	3,980	6,120	----	----	----
SITE INDEX 120						
50	----	----	2,810	4,150	5,730	7,600
100	1,090	2,530	4,230	6,200	8,470	11,070
150	1,290	3,080	5,130	7,440	10,020	12,870
200	1,470	3,520	5,830	8,360	11,100	----
250	1,670	3,960	6,480	9,170	----	----
300	1,910	4,410	7,120	9,960	----	----
350	2,180	4,910	7,790	----	----	----
SITE INDEX 130						
50	----	----	3,360	5,040	7,080	9,530
100	1,240	2,970	5,080	7,600	10,590	14,130
150	1,460	3,630	6,210	9,220	12,700	----
200	1,680	4,190	7,140	10,490	----	----
250	1,920	4,760	8,020	11,660	----	----
300	2,220	5,370	8,920	12,830	----	----
350	2,560	6,030	9,850	----	----	----

[1] Only trees 4.5 inches d.b.h. and larger are included.

Table 3.—Cubic-foot yield of wood and bark to a 4-inch top, outside bark, for unthinned yellow-poplar stands of various stand densities, site indices, and ages[1]

Trees per acre (number)	Age (years)					
	20	30	40	50	60	70
SITE INDEX 90						
	Cubic feet per acre					
50	----	----	1,470	2,050	2,700	3,410
100	640	1,380	2,170	2,990	3,860	4,750
150	730	1,640	2,560	3,470	4,380	5,260
200	810	1,810	2,800	3,740	4,620	5,420
250	900	1,960	2,990	3,930	4,760	5,470
300	1,010	2,110	3,160	4,080	----	----
350	1,130	2,270	3,330	----	----	----
SITE INDEX 100						
50	----	----	1,810	2,590	3,460	4,450
100	740	1,670	2,690	3,800	4,990	6,280
150	860	1,990	3,190	4,440	5,740	7,050
200	950	2,220	3,540	4,850	6,150	7,400
250	1,060	2,430	3,820	5,160	6,430	7,610
300	1,180	2,640	4,090	5,440	----	----
350	1,330	2,860	4,360	----	----	----
SITE INDEX 110						
50	----	----	2,210	3,220	4,380	5,720
100	860	2,000	3,300	4,760	6,380	8,190
150	990	2,400	3,950	5,620	7,430	9,340
200	1,100	2,700	4,420	6,220	8,080	9,990
250	1,240	2,980	4,830	6,710	8,600	10,460
300	1,390	3,280	5,240	7,180	----	----
350	1,570	3,600	5,650	----	----	----
SITE INDEX 120						
50	----	----	2,670	3,950	5,470	7,260
100	980	2,370	4,000	5,890	8,070	10,570
150	1,140	2,860	4,830	7,050	9,520	12,260
200	1,280	3,250	5,470	7,900	10,530	----
250	1,440	3,640	6,060	8,640	----	----
300	1,640	4,040	6,650	9,370	----	----
350	1,870	4,490	7,250	----	----	----
SITE INDEX 130						
50	----	----	3,190	4,810	6,770	9,110
100	1,120	2,780	4,810	7,240	10,110	13,500
150	1,310	3,390	5,870	8,760	12,100	----
200	1,480	3,900	6,730	9,950	----	----
250	1,690	4,410	7,540	11,040	----	----
300	1,940	4,960	8,380	----	----	----
350	2,230	5,560	9,240	----	----	----

[1] Only trees 4.5 inches d.b.h. and larger are included.

Table 4.—Cubic-foot yield of wood only to a 4-inch top, outside bark, for unthinned yellow-poplar stands of various stand densities, site indices, and ages[1]

SITE INDEX 90

Trees per acre (number)	Age (years)					
	20	30	40	50	60	70
	Cubic feet per acre					
50	----	----	1,220	1,700	2,240	2,840
100	520	1,140	1,790	2,480	3,200	3,950
150	590	1,340	2,110	2,870	3,620	4,360
200	650	1,480	2,300	3,090	3,820	4,490
250	720	1,600	2,460	3,240	3,930	4,520
300	800	1,710	2,590	3,360	----	----
350	890	1,840	2,730	----	----	----
SITE INDEX 100						
50	----	----	1,500	2,150	2,880	3,700
100	600	1,380	2,230	3,150	4,150	5,220
150	690	1,640	2,640	3,680	4,760	5,860
200	760	1,820	2,920	4,010	5,090	6,140
250	840	1,990	3,150	4,260	5,320	6,300
300	940	2,150	3,360	4,490	----	----
350	1,060	2,330	3,580	----	----	----
SITE INDEX 110						
50	----	----	1,840	2,670	3,640	4,760
100	700	1,650	2,730	3,950	5,300	6,810
150	800	1,970	3,270	4,660	6,170	7,760
200	890	2,220	3,650	5,150	6,710	8,290
250	990	2,450	3,990	5,560	7,130	8,680
300	1,110	2,690	4,320	5,930	----	----
350	1,260	2,940	4,650	----	----	----
SITE INDEX 120						
50	----	----	2,220	3,290	4,550	6,040
100	810	1,960	3,320	4,900	6,710	8,790
150	930	2,360	4,000	5,850	7,910	10,190
200	1,040	2,680	4,530	6,550	8,740	----
250	1,160	2,990	5,010	7,170	----	----
300	1,320	3,330	5,500	7,760	----	----
350	1,500	3,690	5,990	----	----	----
SITE INDEX 130						
50	----	----	2,650	4,000	5,630	7,590
100	920	2,300	3,990	6,010	8,410	11,230
150	1,070	2,800	4,870	7,280	10,060	----
200	1,200	3,200	5,580	8,260	----	----
250	1,370	3,640	6,250	9,160	----	----
300	1,570	4,090	6,940	----	----	----
350	1,800	4,580	7,640	----	----	----

[1] Only trees 4.5 inches d.b.h. and larger are included.

Table 5.—International ¼-inch board-foot yield to an 8-inch top, outside bark, for unthinned yellow-poplar stands of various stand densities, site indices, and ages[1]

Trees per acre (number)	Age (years)					
	20	30	40	50	60	70
	Board feet per acre					
SITE INDEX 90						
50	----	----	5,180	8,490	12,240	16,480
100	260	2,480	6,260	10,750	15,670	20,920
150	140	2,090	5,960	10,690	15,730	20,830
200	80	1,630	5,210	9,750	14,530	19,120
250	40	1,230	4,370	8,540	12,920	17,000
300	20	880	3,520	7,230	----	----
350	10	590	2,670	----	----	----
SITE INDEX 100						
50	----	----	7,120	11,590	16,790	22,830
100	460	3,760	9,020	15,270	22,270	29,990
150	290	3,420	9,100	15,940	23,370	31,170
200	180	2,930	8,540	15,430	22,770	30,150
250	120	2,460	7,780	14,510	21,580	28,460
300	80	2,040	6,960	13,410	----	----
350	50	1,640	6,070	----	----	----
SITE INDEX 110						
50	----	----	9,400	15,310	22,370	30,720
100	750	5,340	12,380	20,810	30,520	41,580
150	520	5,160	13,070	22,580	33,190	44,760
200	370	4,750	12,950	22,890	33,740	45,150
250	270	4,330	12,550	22,670	33,550	44,630
300	210	3,940	12,050	22,230	----	----
350	170	3,550	11,450	----	----	----
SITE INDEX 120						
50	----	----	12,070	19,740	29,080	40,440
100	1,120	7,250	16,390	27,530	40,710	56,250
150	850	7,370	17,970	30,830	45,640	62,420
200	660	7,170	18,570	32,420	48,000	----
250	550	6,960	18,870	33,410	----	----
300	470	6,780	19,080	34,200	----	----
350	420	6,600	19,190	----	----	----
SITE INDEX 130						
50	----	----	15,160	24,950	37,190	52,270
100	1,600	9,500	21,120	35,590	53,220	74,650
150	1,310	10,070	23,880	40,940	61,220	----
200	1,100	10,270	25,560	44,350	----	----
250	990	10,470	26,960	47,180	----	----
300	940	10,740	28,320	----	----	----
350	920	11,050	----	----	----	----

[1] Only trees 11.0 inches d.b.h. and larger are included.

Table 6.—Averages of actual and estimated yields for the 141 sample stands

Yield basis	Average actual volume of stand	Average difference between actual and estimated volume	Standard deviation of differences
Total cubic-foot volume	5,060	3	1,010
Cubic-foot volume of wood and bark to a 4.0-inch top	4,740	3	970
Cubic-foot volume of wood only to a 4.0-inch top	3,920	2	810
Board-foot volume	17,100	445	5,380

Table 7.—Actual and estimated per-acre volumes for an independent sample of six yellow-poplar stands

Plot	Age	Site index	Number of trees	Total cubic-foot volume			Board-foot volume		
				Actual	Estimated	Difference	Actual	Estimated	Difference
				- - - - - *Cubic feet* - - - - - - - -			- - - - - - *Board feet* - - - - -		
1	38	130	88	5,380	4,300	+1,080	23,180	17,550	+5,630
2	39	133	288	9,110	8,960	+150	29,720	29,480	+240
3	48	130	184	7,110	9,440	—2,330	27,460	39,620	—12,160
4	67	91	168	5,780	5,380	+400	20,720	19,720	+1,000
5	23	124	156	1,770	1,980	—210	1,490	3,240	—1,750
6	39	97	128	3,650	2,890	+760	12,600	7,680	+4,920
Sum				32,800	32,950	—150	115,170	117,290	—2,120
Average volume/acre				5,470	5,490	—25	19,190	19,550	—350

will be slight. Unless the user has independent estimates of mortality in his stands, he can assume that the number of trees per acre will not change over short time periods.

Within the stated limitations, the information presented here can serve as a valuable guide to management planning. Use of the equations and tables requires only a knowledge of the age, site index, and number of trees per acre in the stand. For example, suppose it is determined that a stand of site index 100 will contain 200 trees per acre ≥ 4.5 inches d.b.h. at 50 years of age. The forest manager may be faced with the decision of whether to liquidate the stand at that age or carry it for a longer period. The information in this paper enables him to make a better-informed decision than has heretofore been possible. At age 50 this stand will have 15,430 board feet of merchantable sawtimber per acre (table 5). Table 9 shows that the sawtimber volume is distributed in 89 trees with diameters ranging from 11 to 18 inches. Pulpwood in the remaining 111 trees can be determined by using the appropriate height from table 14 and a specified diameter in equation 6 to determine the volumes of the various diameter classes. Then, by applying the frequency distribution of trees from table 9 it can be determined that 1,210 cubic feet or 15 cords of pulpwood per acre are present in the 5- to 10-inch diameter classes.[8] On the other hand, if the manager holds the stand to age 60, assuming no change in number of trees, he would have 22,770 board feet of sawtimber plus 13 cords of pulpwood per acre. Distribution by tree size would be as shown in table 9 for age 60 at the level of 200 trees per acre. Similarly, he could obtain yield combinations and size-class distribution at any age up to 70 years. With this information, the manager is in a position to make his decision within the framework of his particular objectives and economic situation.

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[8] A conversion factor of 80 cubic feet of wood per standard cord is assumed. No allowance is made for pulpwood in tops of sawtimber trees.

APPENDIX

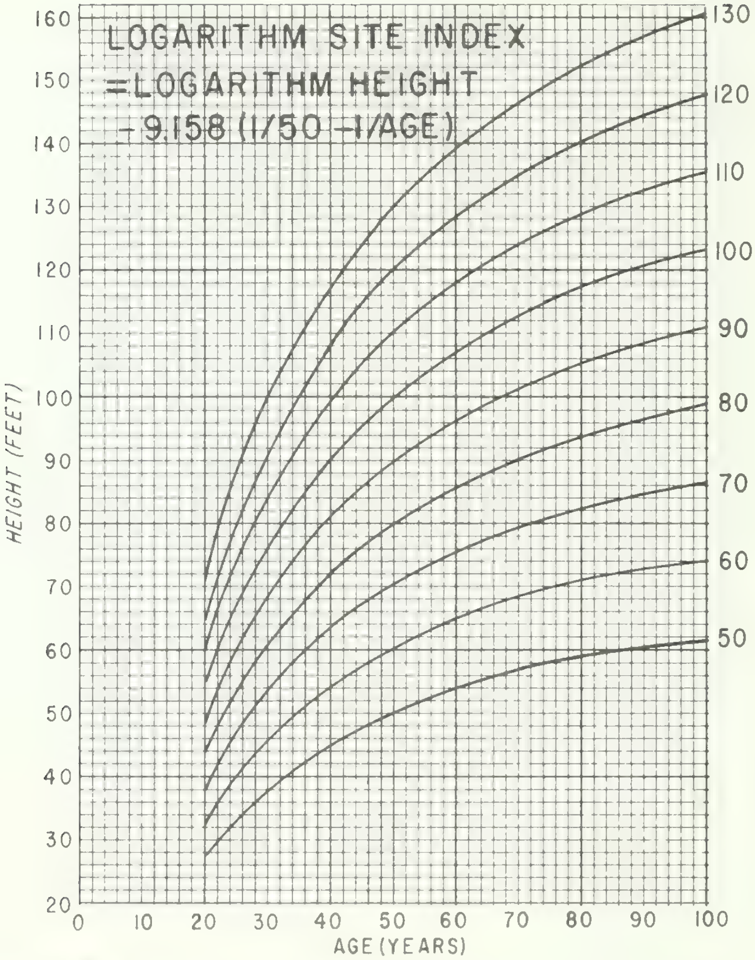

Figure 3.—Site index curves at an index age of 50 years for yellow-poplar in the southern Appalachian Mountains. (Reprint of figure 2 in: Beck, D. E. Yellow-poplar site index curves. USDA Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 180, 2 pp. 1962.)

Table 8.—Diameter distributions for pure natural yellow-poplar stands by age and stand density per acre on site index 90[1]

Total trees (Number)	Basal area (Sq. feet)	Number of trees per diameter class (inches)																									
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AGE 20																											
100	33	15	21	19	16	12	9	5	3																		
150	38	48	37	25	17	11	7	4	1																		
200	43	95	47	26	15	9	5	2	1																		
250	48	145	53	26	14	7	4	1	....																		
300	54	194	57	26	13	6	3	1	....																		
350	61	242	61	26	12	6	2	1	....																		
AGE 30																											
100	51	3	8	13	14	15	14	12	10	7	4																
150	61	12	23	25	24	21	17	13	9	5	1																
200	70	29	39	36	30	24	18	13	8	3	....																
250	77	51	56	46	35	26	18	11	6	1	....																
300	84	77	72	54	39	27	17	10	4	....	....																
350	90	105	87	62	42	28	17	8	1	....	....																
AGE 40																											
50	44	....	....	1	2	4	5	6	6	7	7	6	4	2													
100	67	1	4	8	10	12	12	12	12	11	9	6	3	....													
150	82	5	14	18	20	20	18	16	14	11	8	5	1	....													
200	91	14	27	30	29	26	22	19	15	10	6	2	....	....													
250	98	28	42	42	37	31	25	19	14	9	3	....	....	....													
300	106	44	59	53	44	35	27	19	13	6	....	....	....	....													
350	113	62	75	64	51	39	28	19	10	2	....	....	....	....													
AGE 50																											
50	55	....	....	1	1	2	3	4	5	5	6	6	6	5	4	2											
100	82	1	3	5	7	9	10	11	11	10	10	9	7	5	2	....											
150	98	4	10	14	16	17	17	16	14	13	11	9	6	3	....	....											
200	110	10	21	25	25	24	22	19	17	14	11	8	4	....	....	....											
250	117	21	34	36	34	30	26	22	18	14	10	5	....	....	....	....											
300	123	34	49	48	42	36	30	23	18	12	7	1	....	....	....	....											
AGE 60																											
50	68	....	....	....	1	2	2	3	3	4	4	5	5	5	5	5	4	2									
100	98	1	2	4	6	7	8	9	9	9	9	9	8	7	6	4	2	....									
150	116	3	8	12	14	14	14	14	14	13	12	10	9	7	5	1	....	....									
200	125	9	19	22	22	22	20	19	16	14	12	10	8	5	2	....	....	....									
250	130	19	31	33	31	28	25	22	18	15	12	9	6	1	....	....	....	....									
AGE 70																											
50	80	....	....	....	1	1	2	2	3	3	3	4	4	4	4	5	4	4	4	2							
100	114	1	2	4	5	6	7	7	7	8	8	8	7	7	7	6	5	4	1	....							
150	132	3	8	11	12	13	13	12	12	11	11	10	9	8	7	5	4	1	....	....							
200	141	9	18	20	20	19	18	17	15	14	12	11	9	8	6	4	....	....	....	....							
250	146	19	30	30	28	26	23	20	17	15	13	11	9	6	3	....	....	....	....	....							

[1] Reprint of table 2 in: McGee, C. E., and Della-Bianca, Lino. Diameter distributions in natural yellow-poplar stands. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-25, 7 pp. 1967.

Table 9.—Diameter distributions for pure natural yellow-poplar stands by age and stand density per acre on site index 100[1]

Total trees (Number)	Basal area (Sq. feet)	Number of trees per diameter class (inches)																									
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AGE 20																											
100	35	13	20	19	16	12	9	6	4	1																	
150	41	43	36	26	18	12	8	5	2	----																	
200	46	84	48	29	18	11	6	3	1	----																	
250	52	129	56	30	17	10	5	2	1	----																	
300	58	173	63	31	17	9	5	2	----	----																	
350	65	214	71	34	17	9	4	1	----	----																	
AGE 30																											
100	56	2	7	11	13	14	14	12	11	8	6	2															
150	68	9	20	23	22	20	18	14	11	8	4	1															
200	77	23	35	34	30	25	20	15	10	6	2	----															
250	87	40	50	44	36	28	21	15	10	5	1	----															
300	94	60	66	54	42	31	22	15	8	2	----	----															
350	103	79	81	64	48	34	23	14	7	----	----	----															
AGE 40																											
50	48	----		1	2	3	4	5	6	6	6	6	6	4	1												
100	74	1	4	6	9	10	11	11	11	11	9	8	6	3	----												
150	91	4	11	16	18	18	17	16	15	13	10	8	4	----	----												
200	104	11	22	26	27	25	22	20	16	13	10	6	2	----	----												
250	113	21	35	38	35	31	27	22	17	13	8	3	----	----	----												
300	122	32	49	49	43	37	30	24	18	12	6	----	----	----	----												
350	131	44	63	60	52	43	34	25	17	10	2	----	----	----	----												
AGE 50																											
50	62	----	----	1	1	2	2	3	4	4	5	5	6	6	5	4	2										
100	95	1	2	4	6	7	8	9	10	10	10	9	8	7	6	3	----										
150	113	3	8	12	13	15	15	15	14	13	12	10	9	7	4	----	----										
200	127	8	17	21	22	22	21	19	17	15	13	11	8	5	1	----	----										
250	137	14	28	31	31	29	26	23	20	17	14	10	6	1	----	----	----										
300	147	23	39	42	39	36	31	27	22	18	13	8	2	----	----	----	----										
AGE 60																											
50	76	----	----	----	1	1	2	2	3	3	4	4	4	5	5	5	4	4	3								
100	115	—	2	3	5	6	7	7	8	8	8	8	8	8	7	6	5	4	----								
150	137	2	6	10	11	12	13	13	13	12	11	11	10	9	7	6	4	----	----								
200	150	6	14	18	19	19	19	18	16	15	14	12	10	9	7	4	----	----	----								
250	159	13	24	27	27	26	24	22	20	17	15	13	10	8	4	----	----	----	----								
AGE 70																											
50	92	----	----	----	1	1	1	2	2	2	3	3	3	4	4	4	4	4	4	4	3	1					
100	136	----	2	3	4	5	5	6	6	7	7	7	7	7	7	6	6	6	5	4	----	----					
150	157	2	6	9	10	11	11	11	11	11	10	10	9	9	8	7	6	6	3	----	----	----					
200	169	7	14	16	17	17	17	16	15	14	13	12	10	9	8	7	6	2	----	----	----	----					
250	179	13	23	25	25	23	22	20	18	16	15	13	11	10	8	6	2	----	----	----	----	----					

[1] Reprint of table 3 in: McGee, C. E., and Della-Bianca, Lino. Diameter distributions in natural yellow-poplar stands. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-25, 7 pp. 1967.

Table 10.—Diameter distributions for pure natural yellow-poplar stands by age and stand density per acre on site index 110[1]

Total trees (Number)	Basal area (Sq. feet)	Number of trees per diameter class (inches)																									
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AGE 20																											
100	37	11	18	18	16	13	10	7	5	2																	
150	44	38	35	26	19	13	9	6	3	1																	
200	50	74	48	30	20	13	8	5	2	----																	
250	56	113	58	34	20	12	7	4	2	----																	
300	63	150	68	37	21	13	7	3	1	----																	
350	72	184	78	41	23	13	7	3	1	----																	
AGE 30																											
100	60	2	6	10	12	13	13	12	11	9	7	4	1														
150	74	8	17	20	21	20	18	15	12	10	6	3	----														
200	86	18	30	32	29	25	21	17	13	9	5	1	----														
250	97	31	44	42	36	30	24	18	13	8	4	----	----														
300	107	45	59	52	43	35	26	19	13	7	1	----	----														
350	117	59	72	63	51	39	29	20	12	5	----	----	----														
AGE 40																											
50	54	----	----	1	2	2	3	4	5	5	6	6	6	5	4	1											
100	83	1	3	5	7	9	10	10	11	10	10	9	7	5	3	----											
150	104	3	9	13	15	16	16	16	15	13	12	10	7	4	1	----											
200	117	8	18	23	24	24	22	20	18	15	12	9	6	1	----	----											
250	129	15	29	33	33	30	27	24	20	16	12	8	3	----	----	----											
300	142	23	40	43	41	37	32	27	22	17	12	6	----	----	----	----											
350	154	30	51	53	50	44	38	31	24	17	10	2	----	----	----	----											
AGE 50																											
50	70	----	----	----	1	1	2	3	3	4	4	5	5	5	5	5	4	3									
100	109	----	2	3	5	6	7	8	8	9	9	9	8	8	7	6	4	1									
150	131	2	6	9	12	13	13	14	13	13	12	11	10	9	7	5	1	----									
200	148	5	13	17	19	20	20	19	17	16	14	13	11	8	6	2	----	----									
250	161	10	22	26	27	27	25	23	21	19	16	14	11	7	2	----	----	----									
300	175	16	30	35	35	34	31	28	24	21	18	14	10	4	----	----	----	----									
AGE 60																											
50	89	----	----	----	1	1	1	2	2	2	3	3	4	4	4	4	5	4	4	4	2						
100	133	----	1	2	4	5	6	6	7	7	7	8	8	7	7	7	6	6	4	2	----						
150	161	2	5	8	9	10	11	11	11	11	11	11	10	9	9	8	7	5	2	----	----						
200	177	4	11	15	16	17	17	16	16	15	14	13	12	10	9	8	6	1	----	----	----						
250	190	9	19	22	24	23	22	21	20	18	16	15	13	11	9	7	1	----	----	----	----						
AGE 70																											
50	109	----	----	----	----	1	1	1	1	2	2	2	3	3	3	4	4	4	4	4	4	4	3				
100	159	----	1	2	3	4	5	5	6	6	6	6	6	6	7	6	6	6	6	5	5	3	----				
150	184	2	5	7	8	9	9	10	10	10	10	9	9	9	8	8	7	7	6	5	2	----	----				
200	209	4	10	13	14	15	15	14	14	13	13	12	11	10	10	9	8	7	6	2	----	----	----				
250	220	9	17	20	21	21	20	19	18	16	15	14	13	12	11	9	8	6	1	----	----	----	----				

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[1] Reprint of table 4 in: McGee, C. E., and Della-Bianca, Lino. Diameter distributions in natural yellow-poplar stands. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-25, 7 pp. 1967.

Table 11.—Diameter distributions for pure natural yellow-poplar stands by age and stand density per acre on site index 120[1]

Total trees (Number)	Basal area (Sq. feet)	Number of trees per diameter class (inches)																									
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AGE 20																											
100	39	10	17	17	16	13	10	8	5	3	1																
150	46	33	33	26	20	15	10	7	4	2	....																
200	54	64	47	32	22	15	10	6	3	1	....																
250	62	97	59	37	23	15	9	6	3	1	....																
300	70	128	70	42	26	16	10	6	2	....	....																
350	80	154	82	48	29	18	11	6	2	....	....																
AGE 30																											
100	67	1	5	8	10	12	12	12	11	10	8	6	4	1													
150	82	6	15	18	19	19	18	16	13	11	8	5	2	....													
200	95	14	26	29	28	25	22	18	15	11	8	4	....	....													
250	108	24	38	39	35	31	26	21	16	11	7	2	....	....													
300	121	34	50	49	43	36	30	23	17	11	6	1	....	....													
350	134	42	62	59	52	43	34	26	18	11	3	....	....	....													
AGE 40																											
50	59	....	....	1	1	2	3	3	4	5	5	5	6	5	5	4	1										
100	93	1	2	4	6	8	9	9	10	10	9	9	8	7	5	3	....										
150	114	2	8	11	14	15	15	15	14	13	12	11	9	7	4	....	....										
200	133	6	15	19	21	22	21	20	18	16	14	12	9	6	1	....	....										
250	148	11	23	28	29	29	27	24	22	19	15	12	8	3	....	....	....										
300	163	16	32	37	38	36	32	29	25	21	16	12	6	....	....	....	....										
350	180	20	40	46	46	43	39	34	29	23	17	11	2	....	....	....	....										
AGE 50																											
50	79	....	....	....	1	1	1	2	3	3	3	4	4	5	5	5	5	4	3	1							
100	122	....	1	3	4	5	6	7	8	8	8	8	8	8	7	7	6	5	1	....							
150	149	1	5	8	10	11	12	12	12	12	12	11	11	10	9	7	5	2	....	....							
200	172	4	10	14	16	17	18	17	17	16	15	14	12	11	9	7	3	....	....	....							
250	188	7	17	21	24	24	23	22	21	19	18	16	14	11	8	4	....	....	....	....							
300	206	10	23	29	31	31	29	28	26	23	20	18	15	11	6	....	....	....	....	....							
AGE 60																											
50	98	....	....	....	1	1	1	1	2	2	2	3	3	3	4	4	4	4	4	4	4	3					
100	154	....	1	2	3	4	4	5	6	6	6	7	7	7	7	7	7	6	6	5	4	....					
150	185	1	4	6	8	9	10	10	10	10	10	10	10	9	9	9	8	7	6	4	....	....					
200	208	3	8	12	14	14	15	15	15	14	14	13	12	11	11	10	8	7	4	....	....	....					
AGE 70																											
50	121	....	....	....	....	....	1	1	1	1	2	2	2	3	3	3	3	4	4	4	4	4	4	4			
100	189	....	1	2	2	3	3	4	4	5	5	5	6	6	6	6	6	6	6	6	6	5	5	2			
150	223	1	3	5	7	7	8	8	9	9	9	9	9	8	8	8	8	8	7	7	6	5	1	....			

[1] Reprint of table 5 in: McGee, C. E., and Della-Bianca, Lino. Diameter distributions in natural yellow-poplar stands. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-25, 7 pp. 1967.

Table 12.—Diameter distributions for pure natural yellow-poplar stands by age and stand density per acre on site index 130[1]

AGE 20

Total trees (Number)	Basal area (Sq. feet)	Number of trees per diameter class (inches)																									
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
100	41	9	16	16	15	13	11	8	6	4	2																
150	50	29	31	26	20	15	11	8	6	3	1																
200	59	55	45	33	23	17	11	8	5	2	1																
250	67	82	58	39	27	18	12	8	4	2	----																
300	77	106	71	46	31	20	13	8	4	1	----																
350	89	125	83	54	36	23	15	9	4	1	----																
AGE 30																											
100	73	1	4	7	9	11	11	11	11	10	9	7	6	3													
150	91	4	12	16	18	18	17	16	14	12	10	7	5	1													
200	105	11	22	26	26	25	22	19	16	13	10	7	3	----													
250	121	18	32	35	34	31	27	23	19	14	10	6	1	----													
300	137	24	42	45	42	37	32	26	21	16	10	5	----	----													
350	154	29	51	54	50	44	38	31	24	17	10	2	----	----													
AGE 40																											
50	65	----	----	----	1	2	2	3	3	4	4	5	5	5	5	5	4	1									
100	104	----	2	4	5	6	8	8	9	9	9	9	8	8	7	5	3	----									
150	128	2	6	9	12	13	14	14	14	13	12	11	10	9	7	4	----	----									
200	150	4	12	16	19	20	20	19	18	17	15	13	11	9	6	1	----	----									
250	170	8	18	24	26	26	26	24	22	20	18	15	12	8	3	--	----	----									
300	190	11	25	31	33	33	32	29	27	24	20	16	12	7	-	----	----	----									
350	211	13	30	38	41	40	38	36	32	28	23	18	11	2	----	----	----	----									
AGE 50																											
50	89	----	----	----	----	1	1	2	2	2	3	3	4	4	4	5	5	5	4	4	1						
100	138	----	1	2	3	4	5	6	7	7	7	8	8	8	7	7	7	6	5	2	----						
150	171	1	4	6	8	10	10	11	11	11	11	11	11	10	9	9	8	6	3	----	----						
200	195	3	8	12	14	15	16	16	16	15	15	14	13	12	11	9	7	4	----	----	----						
250	221	5	13	17	20	21	21	21	20	19	18	17	16	14	12	10	6	----	----	----	----						
AGE 60																											
50	116	----	----	----	----	1	1	1	1	1	2	2	2	3	3	3	4	4	4	4	4	4	4	2			
100	176	----	1	2	2	3	4	4	5	5	6	6	6	6	6	7	6	6	6	6	6	5	2	----			
150	217	1	3	5	6	7	8	9	9	9	9	9	9	9	9	9	9	8	7	7	6	2	----	----			
AGE 70																											
50	125	----	----	----	----	-	--	1	1	1	1	1	2	2	2	2	3	3	3	3	3	4	4	4	4	4	2
100	206	----	1	1	2	2	3	3	4	4	4	4	5	5	5	5	5	6	6	6	6	6	6	5	5	1	----

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[1] Revision of table 6 in: McGee, C. E., and Della-Bianca, Lino. Diameter distributions in natural yellow-poplar stands. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-25, 7 pp. 1967.

Table 13.—Total height by diameter class for pure natural yellow-poplar stands of various ages and stand densities on site index 90

Trees per acre (number)	Total height (feet) by diameter class (inches)																									
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AGE 20																										
100	47	48	48	49	49	49	50	50	50																	
150	49	49	49	49	50	50	50	50	50																	
200	50	50	50	50	50	50	50	50	----																	
250	50	50	50	50	50	50	50	50	----																	
300	50	50	50	50	50	50	50	50	----																	
350	50	50	50	50	50	50	50	----	----																	
AGE 30																										
100	48	53	57	60	62	64	66	68	69	70	71															
150	50	55	58	61	64	65	67	68	70	71	----															
200	52	56	59	62	64	66	68	69	70	71	----															
250	53	57	60	63	65	67	68	70	71	----	----															
300	54	58	61	64	66	68	69	70	71	----	----															
350	55	59	62	65	67	68	70	71	----	----	----															
AGE 40																										
50	44	51	57	62	66	70	73	75	77	79	81	83	84													
100	47	54	60	65	68	72	74	77	79	81	82	84	85													
150	49	56	62	66	70	73	76	78	80	82	83	85	----													
200	51	58	63	68	71	74	77	79	81	83	84	----	----													
250	53	59	65	69	73	76	78	80	82	84	----	----	----													
300	54	61	66	70	74	77	79	81	83	85	----	----	----													
350	55	62	67	72	75	78	81	83	84	----	----	----	----													
AGE 50																										
50	43	51	58	64	69	73	76	79	82	85	87	89	90	92	93											
100	46	54	61	66	71	75	78	81	84	86	88	90	92	93	----											
150	48	56	63	68	73	77	80	83	86	88	90	92	93	95	----											
200	50	58	65	70	75	79	82	85	87	89	91	93	94	----	----											
250	52	60	66	72	76	80	83	86	89	91	93	94	----	----	----											
300	53	62	68	74	78	82	85	88	90	92	94	----	----	----	----											
AGE 60																										
50	41	50	58	64	69	74	78	82	85	87	90	92	94	96	97	99	100									
100	45	54	61	67	72	77	81	84	87	89	92	94	96	97	99	100	----									
150	47	56	63	69	74	79	83	86	89	91	93	96	97	99	101	----	----									
200	49	58	65	71	76	81	84	88	90	93	95	97	99	101	----	----	----									
250	51	60	67	73	78	82	86	89	92	95	97	99	101	----	----	----	----									
AGE 70																										
50	40	49	57	64	70	75	79	83	86	89	92	94	96	98	100	101	103	104	106							
100	44	53	60	67	73	77	82	85	88	91	94	96	98	100	102	103	105	106	----							
150	46	55	63	69	75	80	84	87	90	93	96	98	100	102	103	105	106	----	----							
200	48	57	65	71	77	82	86	89	92	95	98	100	102	103	105	107	----	----	----							
250	50	59	67	73	79	84	88	91	94	97	100	102	104	105	----	----	----	----	----							

Table 14.—Total height by diameter class for pure natural yellow-poplar stands of various ages and stand densities on site index 100

Trees per acre (number)	Total height (feet) by diameter class (inches)																								
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AGE 20																										
100	49	50	52	53	53	54	54	55	55																	
150	50	52	53	53	54	54	55	55	55																	
200	51	53	53	54	54	55	55	55	55																	
250	52	53	54	54	55	55	55	55	----																	
300	53	54	54	55	55	55	55	55	----																	
350	54	54	55	55	55	55	55	55	----																	
AGE 30																										
100	49	55	60	64	67	70	72	74	75	77	78	79														
150	51	57	61	65	68	71	73	75	76	78	79	----														
200	53	58	63	66	69	72	74	75	77	78	----	----														
250	54	59	64	67	70	72	74	76	78	79	----	----														
300	55	61	65	68	71	73	75	77	78	----	----	----														
350	56	62	66	69	72	74	76	78	79	----	----	----														
AGE 40																										
50	44	53	60	65	70	74	78	81	84	86	88	90	92	93												
100	48	56	62	68	73	77	80	83	85	88	90	91	93	94												
150	50	58	64	70	74	78	81	84	87	89	91	93	94	----												
200	52	60	66	71	76	80	83	86	88	90	92	94	----	----												
250	53	61	68	73	77	81	84	87	89	91	93	----	----	----												
300	55	63	69	74	79	82	85	88	91	93	94	----	----	----												
350	56	64	71	76	80	84	87	90	92	94	----	----	----	----												
AGE 50																										
50	43	52	60	67	72	77	81	85	88	91	94	96	98	100	102	104	105									
100	46	55	63	69	75	80	84	87	90	93	96	98	100	102	103	105	----									
150	48	58	65	72	77	82	86	89	92	95	97	99	101	103	105	----	----									
200	50	59	67	74	79	83	87	91	94	96	99	101	103	105	----	----	----									
250	52	61	69	75	81	85	89	93	95	98	100	103	104	----	----	----	----									
300	54	63	71	77	82	87	91	94	97	100	102	104	----	----	----	----	----									
AGE 60																										
50	41	51	59	67	73	78	83	87	91	94	97	99	102	104	106	108	109	111	112							
100	45	54	63	70	76	81	86	90	93	96	99	101	104	106	108	109	111	112	----							
150	47	57	65	72	78	83	88	92	95	98	101	103	106	108	109	111	113	----	----							
200	49	59	67	74	80	85	90	94	97	100	103	105	107	109	111	113	----	----	----							
250	51	61	69	76	82	87	92	96	99	102	105	107	109	111	----	----	----	----	----							
AGE 70																										
50	40	50	59	66	73	79	83	88	92	95	98	101	104	106	108	110	112	113	115	116	118					
100	43	53	62	70	76	82	86	91	94	98	101	103	106	108	110	112	114	115	117	118	----					
150	46	56	65	72	78	84	89	93	97	100	103	105	108	110	112	114	115	117	118	----	----					
200	48	58	67	74	81	86	91	95	99	102	105	107	110	112	114	116	117	----	----	----	----					
250	49	60	69	76	83	88	93	97	101	104	107	110	112	114	116	118	----	----	----	----	----					

Table 15.—Total height by diameter class for pure natural yellow-poplar stands of various ages and stand densities on site index 110

AGE 20

Trees per acre (number)	Total height (feet) by diameter class (inches)																									
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
100	50	52	54	56	57	58	59	60	60	61																
150	51	54	55	57	58	59	60	60	61	61																
200	52	55	56	57	58	59	60	60	61	----																
250	53	55	57	58	59	60	60	61	61	----																
300	54	56	57	58	59	60	60	61	61	----																
350	55	57	58	59	59	60	61	61	----	----																
AGE 30																										
100	49	56	62	67	71	74	77	79	81	83	85	86														
150	51	58	64	68	72	75	78	80	82	84	86	87														
200	53	60	65	70	73	76	79	81	83	85	86	----														
250	54	61	66	71	74	77	80	82	84	86	87	----														
300	56	62	68	72	75	78	81	83	85	86	----	----														
350	57	63	69	73	76	79	82	84	86	87	----	----														
AGE 40																										
50	44	53	61	68	73	78	83	86	89	92	95	97	99	101	103											
100	47	57	64	71	76	81	85	88	91	94	96	99	101	102	104											
150	50	59	66	73	78	83	86	90	93	96	98	100	102	104	----											
200	51	61	68	74	80	84	88	91	94	97	99	101	103	----	----											
250	53	62	70	76	81	86	89	93	96	98	101	103	----	----	----											
300	55	64	71	78	83	87	91	94	97	100	102	104	----	----	----											
350	56	65	73	79	84	89	92	96	99	101	103	----	----	----	----											
AGE 50																										
50	42	52	61	69	75	81	86	90	94	97	100	103	106	108	110	112	114	115								
100	46	56	64	72	78	84	88	93	96	100	102	105	107	110	112	113	115	----								
150	48	58	67	74	80	86	90	95	98	101	104	107	109	111	113	115	----	----								
200	50	60	69	76	82	88	92	96	100	103	106	108	111	113	115	----	----	----								
250	51	62	71	78	84	89	94	98	102	105	108	110	112	114	----	----	----	----								
300	53	64	72	80	86	91	96	100	104	107	109	112	114	----	----	----	----	----								
AGE 60																										
50	41	51	61	69	76	82	87	92	96	100	103	106	109	111	114	116	118	120	121	123						
100	44	55	64	72	79	85	90	95	99	102	106	108	111	114	116	118	120	121	123	----						
150	46	57	66	74	81	87	92	97	101	104	108	110	113	115	118	120	121	123	----	----						
200	48	59	68	76	83	89	94	99	103	106	110	112	115	117	119	121	123	----	----	----						
250	50	61	70	78	85	91	96	101	105	108	112	114	117	119	121	123	----	----	----	----						
AGE 70																										
50	39	50	60	68	75	82	87	92	97	101	104	108	111	113	116	118	120	122	124	126	127	129	130			
100	43	54	63	71	79	85	91	95	100	104	107	110	113	116	118	120	122	124	126	127	129	----	----			
150	45	56	66	74	81	87	93	98	102	106	109	112	115	118	120	122	124	126	128	129	----	----	----			
200	47	58	68	76	83	90	95	100	104	108	111	114	117	120	122	124	126	128	130	----	----	----	----			
250	48	60	70	78	85	92	97	102	106	110	114	117	119	122	124	126	128	130	----	----	----	----	----			

Table 16.—Total height by diameter class for pure natural yellow-poplar stands of various ages and stand densities on site index 120

Trees per acre (number)	Total height (feet) by diameter class (inches)																									
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AGE 20																										
100	50	54	57	59	61	62	63	64	65	66																
150	52	55	58	60	61	63	64	65	66	66																
200	53	56	59	61	62	63	64	65	66	67																
250	54	57	59	61	63	64	65	66	66	----																
300	55	58	60	62	63	64	65	66	67	----																
350	56	58	61	62	63	65	65	66	67	----																
AGE 30																										
100	49	57	64	69	74	78	81	84	87	89	91	93	95													
150	51	59	66	71	76	79	83	86	88	90	92	94	----													
200	53	61	67	72	77	81	84	87	89	91	93	95	----													
250	54	62	68	74	78	82	85	88	90	92	94	----	----													
300	55	63	70	75	79	83	86	89	91	93	95	----	----													
350	57	65	71	76	80	84	87	90	92	94	----	----	----													
AGE 40																										
50	43	54	62	70	76	82	87	91	95	98	101	104	106	108	110	112										
100	47	57	65	73	79	84	89	93	97	100	103	105	108	110	112	114										
150	49	59	68	75	81	86	91	95	98	102	104	107	109	111	113	----										
200	51	61	69	77	83	88	93	97	100	103	106	108	111	113	----	----										
250	52	63	71	78	84	90	94	98	102	105	107	110	112	----	----	----										
300	54	64	73	80	86	91	96	100	103	106	109	111	113	----	----	----										
350	55	66	74	82	88	93	97	101	105	108	110	113	----	----	----	----										
AGE 50																										
50	41	52	62	70	78	84	90	94	99	103	106	109	112	115	117	120	122	124	125							
100	45	56	65	74	81	87	92	97	101	105	109	112	114	117	119	121	123	125	----							
150	47	58	68	76	83	89	95	99	103	107	111	114	116	119	121	123	125	----	----							
200	49	60	70	78	85	91	97	101	105	109	112	115	118	120	123	125	----	----	----							
250	50	62	72	80	87	93	98	103	107	111	114	117	120	122	124	----	----	----	----							
300	52	64	73	82	89	95	100	105	109	113	116	119	122	124	----	----	----	----	----							
AGE 60																										
50	40	51	61	70	78	85	91	96	101	105	109	112	116	118	121	124	126	128	130	132	133	135				
100	43	54	65	73	81	88	94	99	104	108	111	115	118	121	123	126	128	130	132	133	135	----				
150	45	57	67	76	84	90	96	101	106	110	114	117	120	123	125	128	130	132	133	135	----	----				
200	47	59	69	78	86	92	98	103	108	112	116	119	122	125	127	129	132	134	----	----	----	----				
AGE 70																										
50	38	50	60	69	77	84	91	96	101	106	110	114	117	120	123	126	128	130	132	134	136	138	139	141		
100	41	53	64	73	81	88	94	100	104	109	113	116	120	123	125	128	130	132	134	136	138	140	141	----		
150	44	56	66	75	83	90	97	102	107	111	115	119	122	125	128	130	132	134	136	138	140	141	----	----		

Table 17.—Total height by diameter class for pure natural yellow-poplar stands of various ages and stand densities on site index 130

Trees per acre (number)	Total height (feet) by diameter class (inches)																									
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AGE 20																										
100	50	54	58	61	64	66	67	69	70	71	72															
150	51	56	60	62	65	66	68	69	71	72	72															
200	53	57	61	63	65	67	69	70	71	72	----															
250	54	58	61	64	66	68	69	70	71	72	----															
300	55	59	62	65	67	68	70	71	72	72	----															
350	56	60	63	65	67	69	70	71	72	----	----															
AGE 30																										
100	48	57	65	71	77	81	85	89	92	95	97	99	101	103												
150	50	59	67	73	78	83	87	90	93	96	98	100	102	----												
200	52	61	68	75	80	84	88	91	94	97	99	101	103	----												
250	53	62	70	76	81	86	89	93	95	98	100	102	----	----												
300	55	64	71	77	82	87	91	94	97	99	101	103	----	----												
350	56	65	72	79	84	88	92	95	98	100	102	----	----	----												
AGE 40																										
50	42	53	63	71	78	85	90	95	99	103	107	110	113	115	118	120	122									
100	46	57	66	74	81	87	93	97	102	105	109	112	114	117	119	121	----									
150	48	59	68	76	83	89	95	99	103	107	110	113	116	118	121	123	----									
200	50	61	70	78	85	91	97	101	105	109	112	115	117	120	122	----	----									
250	51	62	72	80	87	93	98	103	107	110	114	116	119	121	----	----	----									
300	53	64	74	82	89	95	100	104	108	112	115	118	121	123	----	----	----									
350	54	66	75	83	90	96	102	106	110	114	117	120	122	----	----	----	----									
AGE 50																										
50	40	52	62	71	79	86	93	98	103	108	112	115	119	122	124	127	129	131	133	135						
100	43	55	66	75	83	90	96	101	106	110	114	118	121	124	126	129	131	133	135	----						
150	46	58	68	77	85	92	98	103	108	112	116	120	123	126	128	131	133	135	----	----						
200	47	60	70	79	87	94	100	105	110	114	118	122	125	128	130	133	135	----	----	----						
250	49	61	72	81	89	96	102	107	112	116	120	124	127	129	132	134	137	----	----	----						
AGE 60																										
50	38	50	61	71	79	87	94	100	105	110	114	118	122	125	128	131	133	136	138	140	142	144	145			
100	42	54	65	74	83	90	97	103	108	113	117	121	124	127	130	133	135	138	140	142	144	145	----			
150	44	56	67	77	85	93	99	105	110	115	119	123	126	130	132	135	137	140	142	144	146	----	----			
AGE 70																										
50	37	49	60	70	79	87	94	100	105	111	115	119	123	127	130	133	135	138	140	142	144	146	148	150	151	153
100	40	52	64	74	82	90	97	103	109	114	118	122	126	129	132	135	138	140	143	145	147	148	150	152	153	----

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Some Applications of the Principle of Conditional Error

by

Benee F. Swindel

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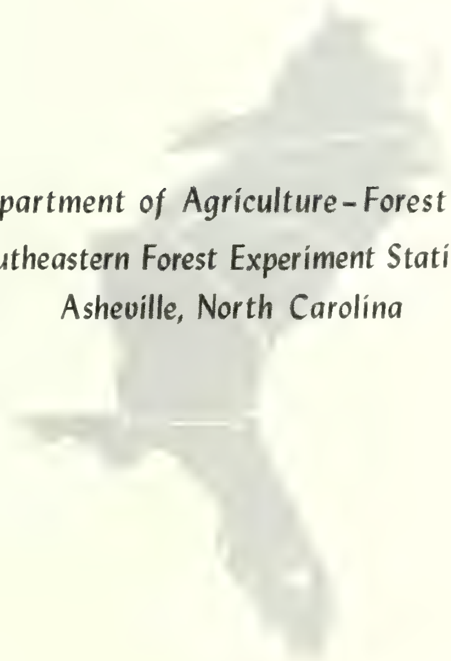

U.S. Department of Agriculture - Forest Service
Southeastern Forest Experiment Station
Asheville, North Carolina

Some Applications of the Principle of Conditional Error

By

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1. INTRODUCTION

The principle of conditional error is a computational procedure for obtaining the sums of squares for testing certain hypotheses. This paper illustrates for the researcher frequently confronted with hypothesis-testing situations the wide applicability of this principle. Those interested in a complete treatment should consult the work of Bose. [1]

A number of substantial benefits accrue to a working knowledge of the principle and the associated test procedure.

First, the generality of the illustrated procedure stimulates an appreciation of the inherent analogies (due to the similarity of the underlying mathematical models) in a number of the traditional analytical procedures. Better understanding and more effective utilization of the classical methods should result.

Second, a working knowledge of the illustrated procedure enables the experimenter to test those linear hypotheses that are most relevant to his particular investigations, whether they are of the traditional types or not. Hopefully, the examples will illustrate this flexibility.

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[1] Bose, R. C. Mimeographed class notes on "Linear Estimation with Fixed Effects and Tests of Linear Hypotheses." Univ. N. C. at Chapel Hill. (Unpublished.)

Finally, it will be seen that the test statistic is computed from residual sums of squares from regression so that existing machine programs for conducting regression analyses can often be used to perform analyses that would otherwise be quite unwieldy.

In the sequel, an acquaintance with the analytical procedures of analysis of variance, analysis of covariance, and regression analysis is assumed. The next section contains a brief description of the unifying concept of the general linear model and a description of the most tractable special cases. The examples are chosen to show how this same simple model is used to describe a variety of superficially different experimental and survey results. The presentation requires the use of some rudimentary concepts from matrix algebra -- these are given in an appendix.

2. A LINEAR MODEL

Most of the observations subjected to statistical analysis are either explicitly or implicitly assumed to be describable as a linear combination of one or more parameters in the following sense. If these parameters were known for some population of individuals, and if the parametric description were employed on different individuals from this population, then the discrepancies between that description and the actual response of the individuals would show no appreciable, detectable systematic patterns; *i.e.*, the discrepancies would be considered random.

Thus, if we denote by Y_j the observed response (or the measure of an attribute) of the j^{th} individual selected from this population, and if we denote by $X_{0j}B_0 + X_{1j}B_1 + X_{2j}B_2 + \dots + X_{mj}B_m$ the parametric description of that individual, the situation is described by the equation

$$Y_j = X_{0j}B_0 + X_{1j}B_1 + X_{2j}B_2 + \dots + X_{mj}B_m + E_j \tag{2.1}$$

where $X_{0j}, X_{1j}, X_{2j}, \dots, X_{mj}$ are determined coefficients peculiar

to the individual, $B_0, B_1, B_2, \dots, B_m$ are the parameters, and E_j is the random discrepancy or "error".

More completely, if we have n observations describable by (2.1) then we write

$$\begin{array}{l} Y_1 = X_{01}B_0 + X_{11}B_1 + X_{21}B_2 + \dots + X_{m1}B_m + E_1 \\ Y_2 = X_{02}B_0 + X_{12}B_1 + X_{22}B_2 + \dots + X_{m2}B_m + E_2 \\ \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \\ Y_n = X_{0n}B_0 + X_{1n}B_1 + X_{2n}B_2 + \dots + X_{mn}B_m + E_n \end{array} \tag{2.2}$$

or, in matrix form,

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \dots \\ Y_n \end{bmatrix} = \begin{bmatrix} X_{01} & X_{11} & X_{21} & \dots & X_{m1} \\ X_{02} & X_{12} & X_{22} & \dots & X_{m2} \\ \dots & \dots & \dots & \dots & \dots \\ X_{0n} & X_{1n} & X_{2n} & \dots & X_{mn} \end{bmatrix} \begin{bmatrix} B_0 \\ B_1 \\ B_2 \\ \dots \\ B_m \end{bmatrix} + \begin{bmatrix} E_1 \\ E_2 \\ \dots \\ E_n \end{bmatrix} \tag{2.2}$$

and finally, using evident shorthand,

$$\underline{Y} = X\underline{B} + \underline{E} . \tag{2.2}$$

Commonly, the parameters are not known, but as a consequence of an experiment or survey, $\underline{\mathbf{Y}}$ and $\mathbf{X}$ only are determined and the objective of subsequent analyses is either

i) to estimate the unknown elements of $\underline{\mathbf{B}}$, or

ii) to test some previously formulated hypotheses about them.

Provided $\mathbf{X}$, $\underline{\mathbf{B}}$, $\underline{\mathbf{E}}$, and $\underline{\mathbf{Y}}$ have the properties about to be described, the principle of conditional error enables the researcher to utilize the observed $\underline{\mathbf{Y}}$ and $\mathbf{X}$ to test any consistent linear hypothesis, H_0, about the elements of $\underline{\mathbf{B}}$; *i.e.*, any hypothesis that is not self-contradictory and can be put into the form

$$
H_0: \quad \begin{array}{ccccccccccc}
a_{01}B_0 & + & a_{11}B_1 & + & a_{21}B_2 & + & \cdots & + & a_{m1}B_m & = & a_1 \\
a_{02}B_0 & + & a_{12}B_1 & + & a_{22}B_2 & + & \cdots & + & a_{m2}B_m & = & a_2 \\
\cdots & & \cdots & & \cdots & & \cdots & & \cdots & & \cdots \\
a_{0k}B_0 & + & a_{1k}B_1 & + & a_{2k}B_2 & + & \cdots & + & a_{mk}B_m & = & a_k
\end{array} \tag{2.3}
$$

where all the a's are specified numbers.

First, the elements of $\underline{\mathbf{X}}$ are assumed to be known fixed[2] numbers and the columns of $\underline{\mathbf{X}}$ are assumed here to be linearly independent.

Second, the elements of $\underline{\mathbf{B}}$ are here assumed to be unknown but fixed numbers.

Third, the elements of $\underline{\mathbf{E}}$ are assumed to be random variables[2] that are normally distributed independently of one another, each having mean 0 and variance σ^2, where σ^2 is constant but unknown.[3] The elements of $\underline{\mathbf{E}}$ are not observable.

---

[2] The significance level of the test procedure to be described has the conventional relative frequency interpretation. By referring to the elements of certain components of a model as fixed, we imply that in the hypothetical sequence of experiments to which we refer for interpretation of probability statements the elements of these components are unchanging. Conversely, when the elements of other components are described as random variables, the implication is that in this hypothetical sequence of experiments these elements are expected to change, assuming values in accordance with some definable probability distribution function, such as the normal.

[3] This assumption may appear to be quite restrictive and it is, on occasion, obviously untenable. Much of the time the researcher employs sufficient randomization to justify the assumption of independence, and sometimes he takes remedial action if he expects differences in the magnitudes of variances {*cf.* Bartlett [3] }. Still, he commonly relies heavily on the central limit theorem as a basis for assuming normality. This theorem suggests that the distribution of the errors likely approaches normality if the individual errors are the composite result of many small influences acting independently of one another.

Finally, the elements of $\underline{\mathbf{Y}}$ are assumed to obey (2.2). The implication is that if the experiment were repeated endlessly {*cf*. footnote 2}, the response of the j^{th} individual to appear in the sample, Y_j, would be distributed normally with mean, or expected value,

$$E(Y_j) = X_{0j}B_0 + X_{1j}B_1 + X_{2j}B_2 + \dots + X_{mj}B_m \tag{2.4}$$

and variance σ^2.

Some conventional computing formulae will now be recorded for subsequent use.

Under the assumptions above, an unbiased estimate of the parameters with good properties is the least squares estimate

$$\hat{\underline{\mathbf{B}}} = \begin{bmatrix} \hat{B}_0 \\ \hat{B}_1 \\ \cdots \\ \hat{B}_m \end{bmatrix} = (\mathbf{X}'\mathbf{X})^{-1} (\mathbf{X}'\underline{\mathbf{Y}}) \tag{2.5}$$

and the unbiased estimate of the expected value of Y_j with smallest variance is

$$\hat{Y}_j = X_{0j}\hat{B}_0 + X_{1j}\hat{B}_1 + X_{2j}\hat{B}_2 + \dots + X_{mj}\hat{B}_m \ .$$

The residual sum of squares or the sum of squares due to error is[4/]

$$SSE = \Sigma\,(Y_j - \hat{Y}_j)^2 \tag{2.6a}$$

$$= \Sigma\,(Y_j^2) - \hat{\underline{\mathbf{B}}}'\ (\mathbf{X}'\,\underline{\mathbf{Y}})\ , \tag{2.6b}$$

This sum of squares has

$$f = n - (m + 1) \tag{2.7}$$

degrees of freedom; *i.e.*, the error degrees of freedom is given by subtracting from the number of observations the number of estimated parameters.

[4/] Σ not indexed means summation over all values of the subscript(s).

3. A TEST PROCEDURE

If in the linear model (2.2) the components have the properties specified above, and one wishes to test a consistent hypothesis, H_0, of the form (2.3), then one method is to

i) select a significance level, α, for the test,

ii) compute the sum of squares due to error, SSE,

iii) find the error degrees of freedom, f, then

iv) reduce the number of parameters in the original model (2.2) by incorporating the hypothesis, H_0. This will lead to a modified or reduced model, say [5]

$$\underline{Y} = X^* \underline{B}^* + \underline{E}^* \quad . \tag{3.1}$$

v) Obtain a conditional sum of squares due to error, SSE*, which is the sum of squares due to error utilizing the model (3.1). Apply (2.5) and (2.6) to (3.1), obtaining

$$\hat{\underline{B}}^* = (X^{*\prime} X^*)^{-1} (X^{*\prime} \underline{Y}) \quad , \text{ and} \tag{3.2}$$

$$\text{SSE}^* = \Sigma (Y_j - \hat{Y}_j^*)^2 \tag{3.3a}$$

$$\Sigma (Y_j^2) - \hat{\underline{B}}^{*\prime} (X^{*\prime} \underline{Y}) \quad . \tag{3.3b}$$

vi) Find the conditional degrees of freedom for error

$$f^* = n - [\text{number of parameters estimated in } (3.2)]. \tag{3.4}$$

---

[5] Throughout this paper an asterisk, *, designates quantities modified as a consequence of this incorporation of the hypothesis into the original model.

The principle of conditional error is that the sum of squares due to the hypothesis, H_0, is given by SSE* - SSE. If H_0 is true,

$$F = \frac{(SSE^* - SSE) \, / \, (f^* - f)}{SSE/f}$$

$$= \frac{f}{(f^* - f)} \cdot \frac{(SSE^* - SSE)}{SSE} \qquad (3.5)$$

is distributed as "Snedecor's F", with (f* - f) degrees of freedom for the numerator and f degrees of freedom for the denominator. Hence, to test H_0 ,

vii) compute F and compare it with the appropriate tabular value. If F exceeds the tabular value, then H_0 is rejected; otherwise it is not.

4. EXAMPLES

Before proceeding, it should be emphasized that simple examples have been chosen as an expediency. Consequently, in some of what follows, the computing associated with formula (3.5) is apparently more laborious than that associated with the more traditional procedures which are given for comparison when they apply. The procedure (3.5) is not recommended for those specific situations where simpler formulas can be applied. Its primary utility is its wide applicability in cases where, because of imbalance in the experimental design or because of peculiarities of the hypothesis, simple computing schemes do not exist. Too, the reader should keep in mind that, in practice, both sums of squares required (*i.e.*, SSE and SSE*) can generally be obtained by using existing machine programs for regression analyses.

The selection of the significance level, α, of particular tests is always left to the individual investigator-- here we arbitrarily fix α at .05 for all tests illustrated.

4.1 Suppose a researcher has n_1 observations, $Y_{11}, Y_{12}, \ldots, Y_{1n_1}$, randomly selected from a normal population with mean μ_1 and variance σ^2, both unknown; and similarly, suppose he has n_2 observations, $Y_{21}, Y_{22}, \ldots, Y_{2n_2}$ from a normal population with mean μ_2 and variance σ^2. Finally, suppose he wishes to test the hypothesis

$$H_0 : \mu_1 = \mu_2 \ .$$

One method of procedure is to compute the familiar statistic

$$t = \frac{\bar{Y}_1 - \bar{Y}_2}{s\sqrt{1/n_1 + 1/n_2}}$$

where $\bar{Y}_1 = \sum_j Y_{1j}/n_1$, $\bar{Y}_2 = \sum_j Y_{2j}/n_2$,

$$s^2 = \frac{\sum_j (Y_{1j} - \bar{Y}_1)^2 + \sum_j (Y_{2j} - \bar{Y}_2)^2}{n_1 + n_2 - 2} \ .$$

If H_0 is true, t is distributed as "Students' t" with $n_1 + n_2 - 2$ degrees of freedom and the hypothesis, H_0, is rejected if and only if the absolute value of t exceeds the appropriate tabular value for two tailed tests.

Another method is to use the techniques of analysis of variance applicable to data subject to a one-way classification as follows

Source	d.f.	SS	MS	F
Populations	1	SSP	MSP = SSP	MSP/MSE
Error	n_1+n_2-2	SSE	MSE = SSE/(n_1+n_2-2)	

where the usual computing formulas for SSP and SSE are

$$\text{SSP} = \frac{(\sum\limits_j Y_{1j})^2}{n_1} + \frac{(\sum\limits_j Y_{2j})^2}{n_2} - \frac{(\sum Y_{ij})^2}{n_1 + n_2}, \text{ and}$$

$$\text{SSE} = \sum Y_{ij}^2 - \frac{(\sum Y_{ij})^2}{n_1 + n_2} - \text{SSP} .$$

If H_0 is true, then F is distributed as "Snedecor's F" with 1 and $n_1 + n_2 - 2$ degrees of freedom and the hypothesis, H_0, is rejected if and only if F exceeds the appropriate tabular value.

Another method of computing F is to utilize (3.5).

The relationship and ultimate equivalency of the first two methods is well known {cf. Snedecor [5] p. 256}, so only the last two methods will be compared in a specific example.

Suppose the results of a particular survey with $n_1 = n_2 = 3$ are

$Y_{11} = 2$ $\qquad$ $Y_{21} = 6$

$Y_{12} = 4$ $\qquad$ $Y_{22} = 2$

$Y_{13} = 3$ $\qquad$ $Y_{23} = 4$

The analysis of variance is

Source	d.f.	SS	MS	F
Populations	1	1.5	1.5	.60
Error	4	10.0	2.5	

and H_0 is not rejected.

Consider now that in the case of the observed responses above, the first three responses would be μ_1 and the second three would be μ_2, except for a random discrepancy; i.e., the appropriate model is

$$Y_{ij} = \mu_i + E_{ij} \qquad \begin{array}{l} i = 1, 2 \\ j = 1, 2, 3 \ ; \end{array}$$

i.e.,

$$\begin{array}{l} Y_{11} = 2 = \mu_1 + E_{11} \\ Y_{12} = 4 = \mu_1 + E_{12} \\ Y_{13} = 3 = \mu_1 + E_{13} \\ Y_{21} = 6 = \mu_2 + E_{21} \\ Y_{22} = 2 = \mu_2 + E_{22} \\ Y_{23} = 4 = \mu_2 + E_{23} \end{array} \quad \text{or} \quad \begin{bmatrix} 2 \\ 4 \\ 3 \\ 6 \\ 2 \\ 4 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} E_{11} \\ E_{12} \\ E_{13} \\ E_{21} \\ E_{22} \\ E_{23} \end{bmatrix}$$

which is clearly of the form $\underline{\mathbf{Y}} = \mathbf{X}\underline{\mathbf{B}} + \underline{\mathbf{E}}$. Here the vector of unknown parameters is

$$\underline{\mathbf{B}} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} .$$

If we now imagine a sequence of repetitions of this survey (in order to interpret the significance level of the test), and if we systematically check the properties of $\mathbf{X}$, $\underline{\mathbf{B}}$, $\underline{\mathbf{E}}$, and $\underline{\mathbf{Y}}$ in this hypothetical sequence, the assumptions of section 2 hold. Hence, we proceed, as indicated in section 3, to utilize (2.6b) and (2.7) to obtain SSE and f.

$$X'X = \begin{bmatrix} 3 & 0 \\ 0 & 3 \end{bmatrix} , \quad X'\underline{Y} = \begin{bmatrix} 9 \\ 12 \end{bmatrix} ,$$

$$\hat{\underline{B}} = (X'X)^{-1}(X'\underline{Y}) = \begin{bmatrix} 1/3 & 0 \\ 0 & 1/3 \end{bmatrix} \begin{bmatrix} 9 \\ 12 \end{bmatrix} = \begin{bmatrix} 3 \\ 4 \end{bmatrix} ,$$

$$\text{SSE} = \Sigma Y_{ij}^2 - \hat{\underline{B}}'(X'\underline{Y})$$

$$= 85 - \begin{bmatrix} 3 & 4 \end{bmatrix} \begin{bmatrix} 9 \\ 12 \end{bmatrix} = 10 \quad ;$$

and, since two parameters (μ_1 and μ_2) have been estimated, SSE has

$$f = n-2 = 6-2 = 4$$

degrees of freedom.

Next, we reduce the number of parameters to be estimated by incorporating $H_0 : \mu_1 = \mu_2$ (or equivalently $H_0 : \mu_1 - \mu_2 = 0$, clearly of the form (2.3)) into the model. Denote by μ^* their (unknown) common value and the model is

$$Y_{ij} = \mu^* + E_{ij}^* \qquad \begin{matrix} i = 1, 2 \\ j = 1, 2, 3 \end{matrix} \quad ;$$

i.e., the modified complete model is

$$\begin{matrix} Y_{11} = 2 = \mu^* + E_{11}^* \\ Y_{12} = 4 = \mu^* + E_{12}^* \\ Y_{13} = 3 = \mu^* + E_{13}^* \\ Y_{21} = 6 = \mu^* + E_{21}^* \\ Y_{22} = 2 = \mu^* + E_{22}^* \\ Y_{23} = 4 = \mu^* + E_{23}^* \end{matrix} \quad \text{or} \quad \begin{bmatrix} 2 \\ 4 \\ 3 \\ 6 \\ 2 \\ 4 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \mu^* + \begin{bmatrix} E_{11}^* \\ E_{12}^* \\ E_{13}^* \\ E_{21}^* \\ E_{22}^* \\ E_{23}^* \end{bmatrix}$$

and this is the model $\underline{\mathbf{Y}} = \mathbf{X}^* \underline{\mathbf{B}}^* + \underline{\mathbf{E}}^*$. Proceeding as directed in section 3, we use (3.3b) and (3.4) to obtain SSE* and f*. Thus,

$$\mathbf{X}^{*\prime}\mathbf{X}^* = [6] \quad , \quad \mathbf{X}^{*\prime}\underline{\mathbf{Y}} = [21] \ ,$$

$$\hat{\underline{\mathbf{B}}}^* = (\mathbf{X}^{*\prime}\mathbf{X}^*)^{-1} (\mathbf{X}^{*\prime}\underline{\mathbf{Y}}) = [1/6]\,[21] = [3.5] \ ,$$

$$\begin{aligned} \text{SSE*} &= \Sigma Y_{ij}^2 - \hat{\underline{\mathbf{B}}}^{*\prime} (\mathbf{X}^{*\prime}\underline{\mathbf{Y}}) \\ &= 85 - [3.5]\,[21] = 11.5 \ , \end{aligned}$$

and, since only one parameter (μ^*) has been estimated, SSE* has

$$f^* = n-1 = 6-1 = 5$$

degrees of freedom.

Finally, utilizing (3.5),

$$F = \frac{f}{(f^* - f)} \cdot \frac{(\text{SSE*} - \text{SSE})}{\text{SSE}} = \frac{4}{(5-4)} \cdot \frac{(11.5 - 10.0)}{10.0} = .60$$

which is the same result as before.

The conclusion in this example is that the observed differences in the response of the two samples could easily have occurred by chance, assuming the true means to be the same; the response is in this sense compatible with the hypothesis and the hypothesis is not rejected.

4.2 Suppose the objective of the researcher had been to utilize the response observed above to test the hypothesis that the two population means are equal and in fact both equal to 6; i.e., the hypothesis is now supposed to be

$$H_0 : \begin{array}{rcl} \mu_1 + 0 \cdot \mu_2 & = & 6 \\ 0 \cdot \mu_1 + \mu_2 & = & 6 \end{array} \ .$$

It may not be clear how to proceed by traditional methods, but since the hypothesis is linear, F can be computed by (3.5). The reduced model, $\underline{Y} = X^* \underline{B}^* + \underline{E}^*$, which includes H_0, is

$$\begin{aligned} Y_{11} &= 2 = 6 + E_{11}^* \\ Y_{12} &= 4 = 6 + E_{12}^* \\ Y_{13} &= 3 = 6 + E_{13}^* \\ Y_{21} &= 6 = 6 + E_{21}^* \\ Y_{22} &= 2 = 6 + E_{22}^* \\ Y_{23} &= 4 = 6 + E_{23}^* \end{aligned} \quad \text{or} \quad \begin{bmatrix} 2 \\ 4 \\ 3 \\ 6 \\ 2 \\ 4 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} [6] + \begin{bmatrix} E_{11}^* \\ E_{12}^* \\ E_{13}^* \\ E_{21}^* \\ E_{22}^* \\ E_{23}^* \end{bmatrix} .$$

Notice that in this case the modified model contains no unknown parameters to be estimated. It should be obvious that, utilizing this model, the best estimate of the expected value of Y_{ij} is always 6; i.e., $Y_{ij}^* \equiv 6$, and so, utilizing (3.3a),

$$SSE^* = \Sigma (Y_{ij} - 6)^2 = 49$$

and, since no parameters have been estimated, SSE* has

$$f^* = n-0 = 6$$

degrees of freedom.

Thus, in this case,

$$F = \frac{f}{(f^* - f)} \cdot \frac{(SSE^* - SSE)}{SSE} = \frac{4}{(6 - 4)} \cdot \frac{(49.0 - 10.0)}{10.0} = 7.8$$

which now exceeds the tabular value, 6.94, for "F" with 2 and 4 degrees of freedom: the hypothesis and the response are incompatible and the hypothesis is rejected.

The next two examples illustrate the application of the principle of conditional error to test hypotheses about the components of an experimental design model. Although $\mathbf{X}$ is dictated by the design, these models are nevertheless often mathematically equivalent to regression models. The most important difference that occurs is that sometimes, in the experimental design models, at least some of the parameters are better considered to be random variables.[6] In these cases hypotheses of interest do not ordinarily take the form (2.3) and the principle of conditional error does not apply. Thus, we consider here only those experimental design models with fixed parameters.

It is also assumed here that the columns of $\mathbf{X}$ are linearly independent. Design models as often formulated do not satisfy this condition. Although the remedies cannot be adequately treated here, a simple example can be used to illustrate the sort of consequences that accompany the failure of this assumption to hold. Consider the application of two "treatments" (to p individuals each) in a completely randomized design. A model frequently used in similar situations is

$$Y_{ij} = \mu + \tau_i + E_{ij} \qquad \begin{array}{l} i = 1, 2 \\ j = 1, 2, \ldots, p \end{array} \qquad ;$$

---

[6] For an account of the classification of design model parameters see Eisenhart [4]. Also see the remarks introducing chapters 13, 14, 22, and 23 of Anderson and Bancroft [2].

i.e., the response of an individual is described as the sum of an overall mean, μ, a treatment effect (τ_1 or τ_2 depending on which treatment has been applied), and a random error, E_{ij}. Suppose, however, that in this example the ideal experimental situation exists; viz, suppose there is no random error. Then all individuals receiving treatment 1 respond alike; their response is $\mu + \tau_1$. Similarly, the response of the remainder is $\mu + \tau_2$. If the response of the first group is 1, say, and that of the second 2, then clearly

$$\begin{aligned} \mu + \tau_1 &= 1 \\ \mu + \tau_2 &= 2 \end{aligned} ,$$

but there is no unique solution for μ, τ_1, and τ_2. From two equations only two parameters could be determined. Similarly, in the more common situation (with error), only two parameters could be estimated. Keeping this in mind, we could reformulate or "reparametrize" the model in terms of two parameters; perhaps in terms of μ_1 and μ_2 {cf. example 4,1}, or perhaps in terms of μ_1 and τ {where μ_1 is the level of response to treatment 1 and τ is the change provoked if the treatment is treatment 2 instead}, or perhaps in some other way. At any rate, something essentially equivalent to this procedure is obviously required to avoid what might be called an overspecification of the model. The assumption of the independence of the columns of $\mathbf{X}$ implies that all the parameters in the chosen model can be estimated and this in turn implies that all hypotheses of the form (2.3) can be tested.

4.3 Suppose a researcher has observed the following response on individuals subject to a two-way classification dependent on the level of two intrinsic or imposed influences that are denoted by "block" and "treatment".

		Treatment			
		1	2	3	4
Block	I	3.4	4.5	4.6	6.9
	II	2.2	1.9	4.2	5.6

If the additional effect of each of the several levels of treatment is expected to be similar in the two blocks (*i.e.*, there is no treatment-block interaction), and if the several levels of treatment are equally spaced (say ascending) rates of application (or lengths of exposure, *etc.*), then the researcher may wish to test the hypothesis

H_0 : response to treatment is linear.

The analysis of variance would be [7]

Source	d.f.	SS	MS	F
Block	1	3.78		
Treatment	3	14.39		
linear component	1	13.34		
deviation from linear	2	1.05	.52	1.24
Error	3	1.25	.42	

and H_0 is not rejected.

---

[7] For a discussion of orthogonal comparisons in this context, see Steel and Torrie [6] p. 222.

The use of this procedure implies the assumption that the underlying model is of the form (2.2). In addition, the assumption of section 2 regarding the random errors is required for the validity of the indicated "F" test. To use the principle of conditional error, the investigator will have to define specifically the applicable model. One way that it can be specified that avoids the overspecification described above is to designate the response in treatment 1 and block 1, say, as a benchmark from which the others are measured (perhaps these represent standard or null levels -- other techniques can be used in other situations). Thus, in the usual model

$$Y_{ij} = \mu + B_i + \tau_j + E_{ij} \qquad \begin{array}{l} i = 1, 2 \\ j = 1, 2, 3, 4 \end{array} ,$$

we have set $B_1 = \tau_1 = 0$ and hence the model, $\underline{\mathbf{Y}} = \mathbf{X}\,\underline{\mathbf{B}} + \underline{\mathbf{E}}$, is

$$\begin{array}{llllllllll}
Y_{11} & = & 3.4 & = & \mu & & & & & + E_{11} \\
Y_{12} & = & 4.5 & = & \mu & & + \tau_2 & & & + E_{12} \\
Y_{13} & = & 4.6 & = & \mu & & & + \tau_3 & & + E_{13} \\
Y_{14} & = & 6.9 & = & \mu & & & & + \tau_4 & + E_{14} \\
Y_{21} & = & 2.2 & = & \mu & + B_2 & & & & + E_{21} \\
Y_{22} & = & 1.9 & = & \mu & + B_2 & + \tau_2 & & & + E_{22} \\
Y_{23} & = & 4.2 & = & \mu & + B_2 & & + \tau_3 & & + E_{23} \\
Y_{24} & = & 5.6 & = & \mu & + B_2 & & & + \tau_4 & + E_{24}
\end{array}$$

$$\text{or} \quad \begin{bmatrix} 3.4 \\ 4.5 \\ 4.6 \\ 6.9 \\ 2.2 \\ 1.9 \\ 4.2 \\ 5.6 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \mu \\ B_2 \\ \tau_2 \\ \tau_3 \\ \tau_4 \end{bmatrix} + \begin{bmatrix} E_{11} \\ E_{12} \\ E_{13} \\ E_{14} \\ E_{21} \\ E_{22} \\ E_{23} \\ E_{24} \end{bmatrix}$$

and in this formulation

μ represents the expected response in block 1 and treatment 1, the check or standard situation,

B_2 represents the additional effect of being in block 2 (as opposed to block 1),

τ_2 represents the additional effect of treatment level 2 (as opposed to level 1),

etc.,

where all of these effects are unknown fixed numbers. Proceeding as directed in Section 3, we find SSE and f.

$$\mathbf{X}'\mathbf{X} = \begin{bmatrix} 8 & 4 & 2 & 2 & 2 \\ 4 & 4 & 1 & 1 & 1 \\ 2 & 1 & 2 & 0 & 0 \\ 2 & 1 & 0 & 2 & 0 \\ 2 & 1 & 0 & 0 & 2 \end{bmatrix}, \quad \mathbf{X}'\underline{\mathbf{Y}} = \begin{bmatrix} 33.3 \\ 13.9 \\ 6.4 \\ 8.8 \\ 12.5 \end{bmatrix},$$

$$\hat{\underline{B}} = (X'X)^{-1}(X'\underline{Y}) = \begin{bmatrix} 5/8 & -1/4 & -1/2 & -1/2 & -1/2 \\ -1/4 & 1/2 & 0 & 0 & 0 \\ -1/2 & 0 & 1 & 1/2 & 1/2 \\ -1/2 & 0 & 1/2 & 1 & 1/2 \\ -1/2 & 0 & 1/2 & 1/2 & 1 \end{bmatrix} \begin{bmatrix} 33.3 \\ 13.9 \\ 6.4 \\ 8.8 \\ 12.5 \end{bmatrix} = \begin{bmatrix} 3.488 \\ -1.375 \\ .400 \\ 1.600 \\ 3.450 \end{bmatrix} ,$$

$$SSE = \Sigma Y_{ij}^{2} - \hat{\underline{B}}' (X'\underline{Y})$$

$$= 158.03 - \begin{bmatrix} 3.488 & -1.375 & .400 & 1.600 & 3.450 \end{bmatrix} \begin{bmatrix} 33.3 \\ 13.9 \\ 6.4 \\ 8.8 \\ 12.5 \end{bmatrix}$$

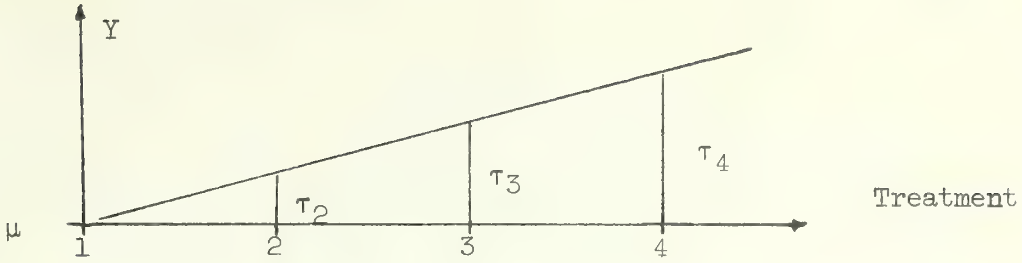
$$= 1.23 \quad ;$$

and, since five parameters have been estimated, SSE has

$$f = n-5 = 8-5 = 3$$

degrees of freedom.

Now consider the hypothesis that response is linear, either increasing linearly with increasing treatment level, or decreasing linearly with increasing level of treatment. Recall that $\tau_1 = 0$ according to the assumed model, so if the hypothesis is true, then in block I the response looks like



or it has the same intercept, μ, but negative slope (and similarly in block II, except the response at level 1 is $\mu + B_2$). From this sketch it can be seen that the hypothesis is

$$H_0 : \begin{array}{l} \tau_3 = 2\tau_2 \\ \tau_4 = 3\tau_2 \end{array} \quad \text{or} \quad \begin{array}{l} 2\tau_2 - \tau_3 = 0 \\ 3\tau_2 - \tau_4 = 0 \end{array} .$$

Incorporating this hypothesis in the model yields

$$\begin{array}{llllllll}
Y_{11} & = & 3.4 & = & \mu & & & + E_{11} \\
Y_{12} & = & 4.5 & = & \mu & & + \tau_2 & + E_{12} \\
Y_{13} & = & 4.6 & = & \mu & & + 2\tau_2 & + E_{13}* \\
Y_{14} & = & 6.9 & = & \mu & & + 3\tau_2 & + E_{14}* \\
Y_{21} & = & 2.2 & = & \mu & + B_2 & & + E_{21} \\
Y_{22} & = & 1.9 & = & \mu & + B_2 & + \tau_2 & + E_{22} \\
Y_{23} & = & 4.2 & = & \mu & + B_2 & + 2\tau_2 & + E_{23}* \\
Y_{24} & = & 5.6 & = & \mu & + B_2 & + 3\tau_2 & + E_{24}*
\end{array}$$

$$\text{or} \quad \begin{bmatrix} 3.4 \\ 4.5 \\ 4.6 \\ 6.9 \\ 2.2 \\ 1.9 \\ 4.2 \\ 5.6 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 1 \\ 1 & 0 & 2 \\ 1 & 0 & 3 \\ 1 & 1 & 0 \\ 1 & 1 & 1 \\ 1 & 1 & 2 \\ 1 & 1 & 3 \end{bmatrix} \begin{bmatrix} \mu \\ B_2 \\ \tau_2 \end{bmatrix} + \begin{bmatrix} E_{11} \\ E_{12} \\ E_{13}^{*} \\ E_{14}^{*} \\ E_{21} \\ E_{22} \\ E_{23}^{*} \\ E_{24}^{*} \end{bmatrix} ,$$

and this is $\underline{\mathbf{Y}} = \mathbf{X}^{*} \underline{\mathbf{B}}^{*} + \underline{\mathbf{E}}^{*}$.

Then $\mathbf{X}^{*\prime}\mathbf{X}^{*} = \begin{bmatrix} 8 & 4 & 12 \\ 4 & 4 & 6 \\ 12 & 6 & 28 \end{bmatrix}$, $\mathbf{X}^{*\prime}\underline{\mathbf{Y}} = \begin{bmatrix} 33.3 \\ 13.9 \\ 61.5 \end{bmatrix}$,

$$\hat{\underline{\mathbf{B}}}^{*} = (\mathbf{X}^{*\prime}\mathbf{X}^{*})^{-1}(\mathbf{X}^{*\prime}\underline{\mathbf{Y}}) = \begin{bmatrix} .475 & -.250 & -.150 \\ -.250 & .500 & 0.000 \\ -.150 & 0.000 & .100 \end{bmatrix} \begin{bmatrix} 33.3 \\ 13.9 \\ 61.5 \end{bmatrix} = \begin{bmatrix} 3.118 \\ -1.375 \\ 1.155 \end{bmatrix} ,$$

$$\begin{aligned} SSE^{*} &= \Sigma Y_{ij}^{2} - \hat{\underline{\mathbf{B}}}^{*\prime} (\mathbf{X}^{*\prime}\underline{\mathbf{Y}}) \\ &= 158.03 - \begin{bmatrix} 3.118 & -1.375 & 1.155 \end{bmatrix} \begin{bmatrix} 33.3 \\ 13.9 \\ 61.5 \end{bmatrix} \\ &= 2.28 \quad ; \end{aligned}$$

and, since three parameters have been estimated, SSE* has

$$f^{*} = n-3 = 8-3 = 5$$

degrees of freedom.

Finally,

$$F = \frac{f}{(f^{*} - f)} \cdot \frac{(SSE^{*} - SSE)}{SSE} = \frac{3}{(5 - 3)} \cdot \frac{(2.28 - 1.23)}{1.23} = 1.28$$

which, aside from the rounding error, is the same result as before.

4.4 Suppose that in example 4.4 the treatment levels had been 0, 1, 2, and 4 so that they are not equally spaced and suppose that otherwise the problem is the same as before. The appropriate general modification of the analysis of variance approach is not easy so only the formula (3.5) is illustrated.

A sketch similar to the one in 4.3 reveals that the hypothesis in quantitative terms is now

$$H_0 : \begin{array}{l} \tau_3 = 2\tau_2 \\ \tau_4 = 4\tau_2 \end{array} \quad \text{or} \quad \begin{array}{l} 2\tau_2 - \tau_3 = 0 \\ 4\tau_2 - \tau_4 = 0 \end{array} .$$

It is easy to see, following the previous example, how the hypothesis is incorporated to produce $\underline{\mathbf{Y}} = \mathbf{X}^* \underline{\mathbf{B}}^* + \underline{\mathbf{E}}^*$.

$$\text{Now } \mathbf{X}^{*\prime}\mathbf{X}^* = \begin{bmatrix} 8 & 4 & 14 \\ 4 & 4 & 7 \\ 14 & 7 & 42 \end{bmatrix} , \quad \mathbf{X}^{*\prime}\underline{\mathbf{Y}} = \begin{bmatrix} 33.3 \\ 13.9 \\ 74.0 \end{bmatrix}$$

$$\hat{\underline{\mathbf{B}}}^* = (\mathbf{X}^{*\prime}\mathbf{X}^*)^{-1}(\mathbf{X}^{*\prime}\underline{\mathbf{Y}}) = \begin{bmatrix} .425 & -.250 & -.100 \\ -.250 & .500 & 0.000 \\ -.100 & 0.000 & .057 \end{bmatrix} \begin{bmatrix} 33.3 \\ 13.9 \\ 74.0 \end{bmatrix} = \begin{bmatrix} 3.278 \\ -1.375 \\ .888 \end{bmatrix} ,$$

$$\begin{aligned} SSE^* &= \Sigma Y_{ij}^2 - \hat{\underline{\mathbf{B}}}^{*\prime}(\mathbf{X}^{*\prime}\underline{\mathbf{Y}}) \\ &= 158.03 - \begin{bmatrix} 3.278 & -1.375 & .888 \end{bmatrix} \begin{bmatrix} 33.3 \\ 13.9 \\ 74.0 \end{bmatrix} \\ &= 2.27 \quad ; \end{aligned}$$

and, since three parameters have been estimated, SSE* has

$$f^* = n-3 = 8-3 = 5$$

degrees of freedom.

Thus,

$$F = \frac{f}{(f^* - f)} \cdot \frac{(SSE^* - SSE)}{SSE} = \frac{3}{(5 - 3)} \cdot \frac{(2.27 - 1.23)}{1.23} = 1.27$$

and again H_0 is not rejected; i.e., the observed response is compatible with the hypothesis that the response to treatment is linear.

4.5 Suppose that eight individuals have been randomly selected from a population and a "treatment" applied to a randomly selected subset of four. Suppose the response, Y, of each individual has been observed, as well as the value of an auxiliary attribute, X_1. Suppose the data are

Untreated		Treated	
Y	X_1	Y	X_1
3.5	1	4.0	1
7.7	2	5.4	2
9.3	2	7.7	2
8.3	1	9.4	2

If the relationship between Y and X_1 is linear and if the slope, B_1, of the regression of Y on X_1 is not affected by the treatment, then the following analysis of covariance is conventionally used to test H_0 : the response, adjusted for the effect of regressionon X_1, is not influenced by treatment.

		SSCP			Adjusted			
Source	d.f.	YY	X_1Y	X_1X_1	d.f.	SS	MS	F
Treatment (T)	1	.661	-.288	.125	1	3.26	3.26	.77
Error (E)	6	36.810	5.225	1.750	5	21.21	4.24	
T + E	7	37.471	4.937	1.875	6	24.47		

In this case H_0 is not rejected for this reason. If the above experiment were repeated a large number of times, then in those with the same observed values of X_1 similar differences in the values of the observed sample means (after adjusting Y for its dependence on X_1) would occur, often by chance in the absence of any real treatment effect. Notice particularly the interpretation of probability statements when the X's are observed; i.e., probability statements are conditional ones. Thus, the interpretation is still based on a sequence of experiments with X unchanging, and this analysis of covariance is based on the assumptions described in section 2. Hence, since the hypothesis is linear, F can be computed by utilizing (3.5).

One appropriate model is

$$Y_{ij} = B_0 + \tau_i + X_{1ij}B_1 + E_{ij} \qquad \begin{array}{l} i = 1, 2 \\ j = 1, 2, 3, 4 \end{array}$$

where $\tau_1 = 0$. Then the response of the untreated individuals is

$$Y_{1j} = B_0 + X_{11j}B_1 + E_{1j} \quad ; \quad j = 1, 2, 3, 4$$

and that of the treated ones is

$$Y_{2j} = B_0 + \tau_2 + X_{12j}B_1 + E_{2j} \quad ; \quad j = 1, 2, 3, 4 \quad .$$

That is

$$\begin{array}{lllllllllll}
Y_{11} & = & 3.5 & = & B_0 & & & + & 1\,B_1 & + & E_{11} \\
Y_{12} & = & 7.7 & = & B_0 & & & + & 2\,B_1 & + & E_{12} \\
Y_{13} & = & 9.3 & = & B_0 & & & + & 2\,B_1 & + & E_{13} \\
Y_{14} & = & 8.3 & = & B_0 & & & + & 1\,B_1 & + & E_{14} \\
Y_{21} & = & 4.0 & = & B_0 & + & \tau_2 & + & 1\,B_1 & + & E_{21} \\
Y_{22} & = & 5.4 & = & B_0 & + & \tau_2 & + & 2\,B_1 & + & E_{22} \\
Y_{23} & = & 7.7 & = & B_0 & + & \tau_2 & + & 2\,B_1 & + & E_{23} \\
Y_{24} & = & 9.4 & = & B_0 & + & \tau_2 & + & 2\,B_1 & + & E_{24}
\end{array}$$

$$\text{or} \quad \begin{bmatrix} 3.5 \\ 7.7 \\ 9.3 \\ 8.3 \\ 4.0 \\ 5.4 \\ 7.7 \\ 9.4 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1 \\ 1 & 0 & 2 \\ 1 & 0 & 2 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 2 \\ 1 & 1 & 2 \\ 1 & 1 & 2 \end{bmatrix} \begin{bmatrix} B_0 \\ \tau_2 \\ B_1 \end{bmatrix} + \begin{bmatrix} E_{11} \\ E_{12} \\ E_{13} \\ E_{14} \\ E_{21} \\ E_{22} \\ E_{23} \\ E_{24} \end{bmatrix} .$$

From this $\mathbf{X}'\mathbf{X} = \begin{bmatrix} 8 & 4 & 13 \\ 4 & 4 & 7 \\ 13 & 7 & 23 \end{bmatrix}$, $\mathbf{X}'\underline{\mathbf{Y}} = \begin{bmatrix} 55.3 \\ 26.5 \\ 94.8 \end{bmatrix}$,

$$\hat{\underline{\mathbf{B}}} = (\mathbf{X}'\mathbf{X})^{-1}(\mathbf{X}'\underline{\mathbf{Y}}) = \begin{bmatrix} 1.5357 & -.0357 & -.8571 \\ -.0357 & .5357 & -.1429 \\ -.8571 & -.1429 & .5714 \end{bmatrix} \begin{bmatrix} 55.3 \\ 26.5 \\ 94.8 \end{bmatrix} = \begin{bmatrix} 2.725 \\ -1.325 \\ 2.984 \end{bmatrix} ,$$

$$\begin{aligned} \text{SSE} &= \Sigma Y_{ij}^2 - \hat{\underline{\mathbf{B}}}'(\mathbf{X}'\underline{\mathbf{Y}}) \\ &= 419.73 - \begin{bmatrix} 2.725 & -1.325 & 2.984 \end{bmatrix} \begin{bmatrix} 55.3 \\ 26.5 \\ 94.8 \end{bmatrix} \\ &= 21.27 \quad ; \end{aligned}$$

and, since three parameters have been estimated, SSE has

$$f = n-3 = 8-3 = 5$$

degrees of freedom.

Now incorporating $H_0 : \tau_2 = 0$ into the model, it becomes

$$\begin{aligned} Y_{11} &= 3.5 = B_0 + 1B_1 + E_{11} \\ Y_{12} &= 7.7 = B_0 + 2B_1 + E_{12} \\ Y_{13} &= 9.3 = B_0 + 2B_1 + E_{13} \\ Y_{14} &= 8.3 = B_0 + 1B_1 + E_{14} \\ Y_{21} &= 4.0 = B_0 + 1B_1 + E_{21}^* \\ Y_{22} &= 5.4 = B_0 + 2B_1 + E_{22}^* \\ Y_{23} &= 7.7 = B_0 + 2B_1 + E_{23}^* \\ Y_{24} &= 9.4 = B_0 + 2B_1 + E_{24}^* \end{aligned} \quad \text{or} \quad \begin{bmatrix} 3.5 \\ 7.7 \\ 9.3 \\ 8.3 \\ 4.0 \\ 5.4 \\ 7.7 \\ 9.4 \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \\ 1 & 2 \\ 1 & 1 \\ 1 & 1 \\ 1 & 2 \\ 1 & 2 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} B_0 \\ B_1 \end{bmatrix} + \begin{bmatrix} E_{11} \\ E_{12} \\ E_{13} \\ E_{14} \\ E_{21}^* \\ E_{22}^* \\ E_{23}^* \\ E_{24}^* \end{bmatrix} ,$$

and this is $\underline{Y} = X^* \underline{B}^* + \underline{E}^*$. Hence,

$$X^{*\prime} X^* = \begin{bmatrix} 8 & 13 \\ 13 & 23 \end{bmatrix} , \quad X^{*\prime}\underline{Y} = \begin{bmatrix} 55.3 \\ 94.8 \end{bmatrix} ,$$

$$\hat{\underline{B}}^{*\prime} = (X^{*\prime}X^*)^{-1}(X^{*\prime}\underline{Y}) = \begin{bmatrix} 1.53333 & -.86667 \\ -.86667 & .53333 \end{bmatrix} \begin{bmatrix} 55.3 \\ 94.8 \end{bmatrix} = \begin{bmatrix} 2.633 \\ 2.633 \end{bmatrix} ,$$

$$\begin{aligned} SSE^* &= \Sigma Y_{ij}^2 - \hat{\underline{B}}^{*\prime}(X^{*\prime}\underline{Y}) \\ &= 419.73 - [2.633 \quad 2.633] \begin{bmatrix} 55.3 \\ 94.8 \end{bmatrix} \\ &= 24.52 \ ; \end{aligned}$$

and, since two parameters have been estimated, SSE* has

$$f^* = n-2 = 8-2 = 6$$

degrees of freedom.

Now,

$$F = \frac{f}{(f^* - f)} \cdot \frac{(SSE^* - SSE)}{SSE} = \frac{5}{(6-5)} \cdot \frac{(25.52 - 21.27)}{21.27}$$

$$= .76$$

and this is the same result as before. The reappearance of the same sums of squares indicates that the two computing procedures are the same except that the order of computations is somewhat changed.

4.6 Suppose now that, in addition to X_1, the values of a second auxiliary variable, X_2, had been known in the previous example. Suppose the complete data are

Untreated			Treated		
Y	X_1	X_2	Y	X_1	X_2
3.5	1	1	4.0	1	0
7.7	2	2	5.4	2	0
9.3	2	3	7.7	2	1
8.3	1	3	9.4	2	2

Suppose all the assumptions for the validity of an analysis of covariance hold[8]. One possible appropriate model is

$$Y_{ij} = B_0 + \tau_1 + X_{1ij}B_1 + X_{2ij}B_2 + E_{ij} \quad ; \quad \begin{array}{l} i = 1, 2 \\ j = 1, 2, 3, 4 \end{array}$$

where, since the first group has not been treated, we take $\tau_1 = 0$. Thus, the response of untreated individuals is described as

$$Y_{1j} = B_0 + X_{11j}B_1 + X_{21j}B_2 + E_{1j} \quad ; \quad j = 1, 2, 3, 4$$

and that of treated individuals as

$$Y_{2j} = B_0 + \tau_2 + X_{12j}B_1 + X_{22j}B_2 + E_{2j} \quad ; \quad j = 1, 2, 3, 4.$$

Thus, the model $\underline{\mathbf{Y}} = \mathbf{X}\underline{\mathbf{B}} + \underline{\mathbf{E}}$ written out in detail is

$$\begin{array}{lllllllllll}
Y_{11} & = & 3.5 & = & B_0 & & & + 1\,B_1 & + & 1\,B_2 & + \; E_{11} \\
Y_{12} & = & 7.7 & = & B_0 & & & + 2\,B_1 & + & 2\,B_2 & + \; E_{12} \\
Y_{13} & = & 9.3 & = & B_0 & & & + 2\,B_1 & + & 3\,B_2 & + \; E_{13} \\
Y_{14} & = & 8.3 & = & B_0 & & & + 1\,B_1 & + & 3\,B_2 & + \; E_{14} \\
Y_{21} & = & 4.0 & = & B_0 & + & \tau_2 & + 1\,B_1 & + & 0\,B_2 & + \; E_{21} \\
Y_{22} & = & 5.4 & = & B_0 & + & \tau_2 & + 2\,B_1 & + & 0\,B_2 & + \; E_{22} \\
Y_{23} & = & 7.7 & = & B_0 & + & \tau_2 & + 2\,B_1 & + & 1\,B_2 & + \; E_{23} \\
Y_{24} & = & 9.4 & = & B_0 & + & \tau_2 & + 2\,B_1 & + & 2\,B_2 & + \; E_{24}
\end{array}$$

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[8] For a good general treatment of analysis of covariance see Steel and Torrie [6] Chap. 15.

$$\text{or}\quad \begin{bmatrix} 3.5 \\ 7.7 \\ 9.3 \\ 8.3 \\ 4.0 \\ 5.4 \\ 7.7 \\ 9.4 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1 & 1 \\ 1 & 0 & 2 & 2 \\ 1 & 0 & 2 & 3 \\ 1 & 0 & 1 & 3 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 2 & 0 \\ 1 & 1 & 2 & 1 \\ 1 & 1 & 2 & 2 \end{bmatrix} \begin{bmatrix} B_0 \\ \tau_2 \\ B_1 \\ B_2 \end{bmatrix} + \begin{bmatrix} E_{11} \\ E_{12} \\ E_{13} \\ E_{14} \\ E_{21} \\ E_{22} \\ E_{23} \\ E_{24} \end{bmatrix} .$$

Suppose, finally, that the hypothesis to be tested is that the effect of treatment is to add four units to the response; i.e., suppose that the hypothesis is now

$$H_0 : \tau_2 = 4.$$

Clearly the procedure (3.5) can be used, so we proceed according to section 3. In this case

$$X'X = \begin{bmatrix} 8 & 4 & 13 & 12 \\ 4 & 4 & 7 & 3 \\ 13 & 7 & 23 & 20 \\ 12 & 3 & 20 & 28 \end{bmatrix} , \qquad X'\underline{Y} = \begin{bmatrix} 55.3 \\ 26.5 \\ 94.8 \\ 98.2 \end{bmatrix} ,$$

$$\hat{\underline{B}} = (X'X)^{-1}(X'\underline{Y}) = \begin{bmatrix} 1.83719 & -.46511 & -.67442 & -.25580 \\ -.47511 & 1.14728 & -.40310 & .36434 \\ -.67442 & -.40310 & .68217 & -.15504 \\ -.25580 & .36434 & -.15504 & .21705 \end{bmatrix} \begin{bmatrix} 55.3 \\ 26.5 \\ 94.8 \\ 98.2 \end{bmatrix}$$

$$= \begin{bmatrix} .2166 \\ 2.2466 \\ 1.4672 \\ 2.1258 \end{bmatrix} ,$$

$$SSE = \Sigma Y_{ij}^2 - \hat{\underline{B}}'(X'\underline{Y})$$

$$= 419.73 - [.2166 \quad 2.2466 \quad 1.4672 \quad 2.1258] \begin{bmatrix} 55.3 \\ 26.5 \\ 94.8 \\ 98.2 \end{bmatrix}$$

$$= .373 \quad ;$$

and, since four parameters have been estimated, SSE has

$$f = n-4 = 8-4 = 4$$

degrees of freedom.

Now, incorporating $H_0: \tau_2 = 4$ into the model, it becomes

$$\begin{array}{lllllllllllll}
Y_{11} & = & 3.5 & = & B_0 & & & + & 1\,B_1 & + & 1\,B_2 & + & E_{11} \\
Y_{12} & = & 7.7 & = & B_0 & & & + & 2\,B_1 & + & 2\,B_2 & + & E_{12} \\
Y_{13} & = & 9.3 & = & B_0 & & & + & 2\,B_1 & + & 3\,B_2 & + & E_{13} \\
Y_{14} & = & 8.3 & = & B_0 & & & + & 1\,B_1 & + & 3\,B_2 & + & E_{14} \\
Y_{21} & = & 4.0 & = & B_0 & + & 4 & + & 1\,B_1 & + & 0\,B_2 & + & E_{21}^* \\
Y_{22} & = & 5.4 & = & B_0 & + & 4 & + & 2\,B_1 & + & 0\,B_2 & + & E_{22}^* \\
Y_{23} & = & 7.7 & = & B_0 & + & 4 & + & 2\,B_1 & + & 1\,B_2 & + & E_{23}^* \\
Y_{24} & = & 9.4 & = & B_0 & + & 4 & + & 2\,B_1 & + & 2\,B_2 & + & E_{24}^*
\end{array}$$

$$\text{or} \quad \begin{bmatrix} 3.5 \\ 7.7 \\ 9.3 \\ 8.3 \\ 0.0 \\ 1.4 \\ 3.7 \\ 5.4 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 2 \\ 1 & 2 & 3 \\ 1 & 1 & 3 \\ 1 & 1 & 0 \\ 1 & 2 & 0 \\ 1 & 2 & 1 \\ 1 & 2 & 2 \end{bmatrix} \begin{bmatrix} B_0 \\ B_1 \\ B_2 \end{bmatrix} + \begin{bmatrix} E_{11} \\ E_{12} \\ E_{13} \\ E_{14} \\ E_{21}^* \\ E_{22}^* \\ E_{23}^* \\ E_{24}^* \end{bmatrix}$$

and this is denoted by $\underline{Y} = X^* \underline{B}^* + \underline{E}^*$.

Then $\mathbf{X}^{*\prime}\mathbf{X}^{*} = \begin{bmatrix} 8 & 13 & 12 \\ 13 & 23 & 20 \\ 12 & 20 & 28 \end{bmatrix}$, $\mathbf{X}^{*\prime}\underline{Y} = \begin{bmatrix} 39.3 \\ 66.8 \\ 86.2 \end{bmatrix}$,

$$\hat{\underline{\boldsymbol{\beta}}}^{*} = (\mathbf{X}^{*\prime}\mathbf{X}^{*})^{-1}(\mathbf{X}^{*\prime}\underline{Y}) = \begin{bmatrix} 1.64862 & -.83783 & -.10810 \\ -.83783 & .54054 & -.02703 \\ -.10810 & -.02703 & .10135 \end{bmatrix} \begin{bmatrix} 39.3 \\ 66.8 \\ 86.2 \end{bmatrix}$$

$$= \begin{bmatrix} -.4945 \\ .8514 \\ 2.6824 \end{bmatrix} ,$$

$$\text{SSE}^{*} = \Sigma Y_{ij}^{2} - \hat{\underline{\boldsymbol{\beta}}}^{*\prime}(\mathbf{X}^{*\prime}\underline{Y})$$

$$= 271.73 - \begin{bmatrix} -.4945 & .8514 & 2.6824 \end{bmatrix} \begin{bmatrix} 39.3 \\ 66.8 \\ 86.2 \end{bmatrix}$$

$$= 3.067 \;;$$

and, since three parameters have been estimated, SSE* has

$$f^{*} = n-3 = 8-3 = 5$$

degrees of freedom.

Hence,

$$F = \frac{f}{(f^{*} - f)} \cdot \frac{(\text{SSE}^{*} - \text{SSE})}{\text{SSE}} = \frac{4}{(5 - 4)} \cdot \frac{(3.067 - .373)}{.373}$$

$$= 28.89$$

and this exceeds the tabular value for 1 and 4 degrees of freedom. Thus, the observed response is incompatible with the hypothesis, H_0, that the effect of treatment is to increase the response by four units and so H_0 is rejected.

In the next three examples we consider the usual regression model where the elements of $\mathbf{X}$ normally assume a variety of values, usually as a consequence of a measurement of some attribute of the observational unit.

For these examples, as in examples 4.5 and 4.6, we still assume that the elements of $\mathbf{X}$ are fixed; i.e., probability statements are conditional ones. This is the usual assumption in regression and it is compatible, for example, with the real world situation where the values of $\mathbf{X}$ are chosen by the experimenter and not left to chance {see Anderson and Bancroft [2] p. 168}.

4.7 Suppose an investigator has n assessments of variables called $Y, X_1, X_2, \ldots, X_m$ and suppose the straightforward regression model

$$Y_j = B_0 + X_{1j}B_1 + X_{2j}B_2 + \ldots + X_{mj}B_m + E_j \quad , \quad j = 1, 2, \ldots , n,$$

describes the relationship between them; i.e., the components of this model all satisfy the conditions of section 2. Further, suppose the investigator wishes to test the hypothesis that the "response", Y, is not influenced by the level of the "independent" variables, $X_1, X_2, \ldots, X_m$; i.e., let the hypothesis be

$$H_0 : \; B_1 = B_2 = \ldots = B_m = 0.$$

The usual test statistic in this case is well known. It can be written

$$F = \frac{SSR/m}{SSE/f} = \frac{f}{m}\,\frac{SSR}{SSE}$$

where SSE is, as above, the residual sum of squares from regression or sum of squares due to error with $f = n - (m + 1)$ degrees of freedom, and SSR is the sum of squares due to regression with m degrees of freedom.

SSR is interpretable as the reduction in the residual sum of squares due to fitting $X_1, X_2, \ldots, X_m$; i.e., SSR is the difference between the total sum of squares "corrected for the mean" and the residual sum of squares from the full model. For example, if $\hat{Y}_j$ is given by

$$\hat{Y}_j = \hat{B}_0 + X_{1j}\hat{B}_1 + X_{2j}\hat{B}_2 + \ldots + X_{mj}\hat{B}_m$$

where the $\hat{B}$'s are determined by (2.5), then

$$\begin{aligned} SSR &= \Sigma (Y_j - \bar{Y})^2 - \Sigma (Y_j - \hat{Y}_j)^2 \\ &= \Sigma (Y_j - \bar{Y})^2 - SSE \end{aligned}$$

Utilizing the principle of conditional error, one is directed to compute

$$F = \frac{f}{(f^* - f)} \cdot \frac{(SSE^* - SSE)}{SSE} .$$

Consider that the model incorporating H_0 is

$$Y_j = B_0^* + E_j^*$$

and it is easy to show that $\hat{B}_0^* = \bar{Y}$. Thus, $\hat{Y}_j^* = \bar{Y}$,

$$\begin{aligned} SSE^* &= \Sigma (Y_j - \hat{Y}_j^*)^2 \\ &= \Sigma (Y_j - \bar{Y})^2 \end{aligned}$$

and, since one parameter has been estimated, SSE* has

$$f^* = n - 1$$

degrees of freedom.

Observe then that (SSE* - SSE) = SSR and that (f* - f) = (n-1) - [n -(m+1)] = m; i.e., formula (3.5) is essentially the traditional methodology for this case.

Suppose, to be specific, that the data are

Y	X_1	X_2
4.4	0	1
6.8	0	3
2.9	3	2
-0.5	3	0

The full model $\underline{Y} = X\underline{B} + \underline{E}$ is

$$\begin{bmatrix} 4.4 \\ 6.8 \\ 2.9 \\ -0.5 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1 \\ 1 & 0 & 3 \\ 1 & 3 & 2 \\ 1 & 3 & 0 \end{bmatrix} \begin{bmatrix} B_0 \\ B_1 \\ B_2 \end{bmatrix} + \begin{bmatrix} E_1 \\ E_2 \\ E_3 \\ E_4 \end{bmatrix} .$$

Then

$$X'X = \begin{bmatrix} 4 & 6 & 6 \\ 6 & 18 & 6 \\ 6 & 6 & 14 \end{bmatrix}, \quad X'\underline{Y} = \begin{bmatrix} 13.6 \\ 7.2 \\ 30.6 \end{bmatrix} ,$$

$$\hat{\underline{B}} = (X'X)^{-1}(X'\underline{Y}) = \begin{bmatrix} 1.50000 & -.33333 & -.50000 \\ -.33333 & .13889 & .08333 \\ -.50000 & .08333 & .25000 \end{bmatrix} \begin{bmatrix} 13.6 \\ 7.2 \\ 30.6 \end{bmatrix} = \begin{bmatrix} 2.7000 \\ -.9834 \\ 1.4500 \end{bmatrix} ,$$

$$\begin{aligned} SSE &= \Sigma Y_i^2 - \hat{\underline{B}}'(X'\underline{Y}) \\ &= 74.26 - \begin{bmatrix} 2.7000 & -.9834 & 1.4500 \end{bmatrix} \begin{bmatrix} 13.6 \\ 7.2 \\ 30.6 \end{bmatrix} \\ &= .250 \ ; \end{aligned}$$

and, since three parameters have been estimated, SSE has

$$f = n-3 = 4-3 = 1$$

degree of freedom.

From the foregoing discussion we have that

$$SSE^* = \Sigma (Y_i - \bar{Y})^2 = \Sigma (Y_i - 3.4)^2$$

$$= 28.02 \text{ , and } f^* = n-1 = 4-1 = 3. \text{ So}$$

$$F = \frac{f}{(f^* - f)} \cdot \frac{(SSE^* - SSE)}{SSE} = \frac{1}{(3-1)} \cdot \frac{(28.02 - .250)}{.250}$$

$$= 55.54$$

and H_0 is not rejected since the tabular value for 2 and 1 degree of freedom is 200.

4.8 Suppose that in example 4.7 the investigator had wished instead to test the hypothesis that the effects of X_1 and X_2 (while possibly not zero) are complementary in the sense that as X_1 and X_2 increase at the same rates their effects are opposite in sign but equal in magnitude; i.e., suppose the hypothesis, H_0, is

$$H_0 : \quad B_2 = -B_1 \qquad \text{or } B_1 + B_2 = 0.$$

Incorporating this hypothesis into the model, it becomes $\mathbf{Y} = \mathbf{X}^* \underline{\mathbf{B}}^* + \underline{\mathbf{E}}^*$, which in detail is

$$\begin{bmatrix} 4.4 \\ 6.8 \\ 2.9 \\ -0.5 \end{bmatrix} = \begin{bmatrix} 1 & -1 \\ 1 & -3 \\ 1 & 1 \\ 1 & 3 \end{bmatrix} \begin{bmatrix} B_0 \\ B_1 \end{bmatrix} + \begin{bmatrix} E_1^* \\ E_2^* \\ E_3^* \\ E_4^* \end{bmatrix} .$$

Then $\mathbf{X}^{*\prime}\mathbf{X}^* = \begin{bmatrix} 4 & 0 \\ 0 & 20 \end{bmatrix}$, $\mathbf{X}^{*\prime}\underline{\mathbf{Y}} = \begin{bmatrix} 13.6 \\ -23.4 \end{bmatrix}$,

$$\hat{\underline{\mathbf{B}}}^* = (\mathbf{X}^{*\prime}\mathbf{X}^*)^{-1}(\mathbf{X}^{*\prime}\underline{\mathbf{Y}}) = \begin{bmatrix} 0.250 & 0.000 \\ 0.000 & 0.050 \end{bmatrix} \begin{bmatrix} 13.6 \\ -23.4 \end{bmatrix} = \begin{bmatrix} 3.40 \\ -1.17 \end{bmatrix} ,$$

$$SSE^* = \Sigma Y_i^2 - \hat{\underline{\mathbf{B}}}^{*\prime}(\mathbf{X}^{*\prime}\underline{\mathbf{Y}})$$

$$= 74.26 - \begin{bmatrix} 3.40 - 1.17 \end{bmatrix} \begin{bmatrix} 13.6 \\ -23.4 \end{bmatrix}$$

$$= .642 \quad ;$$

and, since two parameters have been estimated, SSE* has

$$f^* = n-2 = 4-2 = 2$$

degrees of freedom. Thus,

$$F = \frac{f}{(f^* - f)} \cdot \frac{(SSE^* - SSE)}{SSE} = \frac{1}{(2-1)} \cdot \frac{(.642 - .250)}{.250}$$

$$= 1.57$$

and H_0 is not rejected; *i.e.*, the response observed and the hypothesis in this case appear to be quite compatible.

4.9 Suppose now that the experiment of 4.7 is repeated so that instead of the four observations the experimenter has data on eight individuals as follows

Y	X_1	X_2	Y	X_1	X_2
4.4	0	1	5.7	0	1
6.8	0	3	7.5	0	3
2.9	3	2	3.2	3	2
- 0.5	3	0	1.9	3	0

If the second group is observed at a different time or place or under different circumstances, then the investigator may reasonably require only that the form of the model remains the same as before; *i.e.*, he may not require of his general model that it have the same coefficients. In that case, the model $\mathbf{Y} = \mathbf{X}\underline{\mathbf{B}} + \underline{\mathbf{E}}$ might be written as

$$\begin{aligned}
Y_1 &= 4.4 = B_0 + 0\,B_1 + 1\,B_2 + E_1 \\
Y_2 &= 6.8 = B_0 + 0\,B_1 + 3\,B_2 + E_2 \\
Y_3 &= 2.9 = B_0 + 3\,B_1 + 2\,B_2 + E_3 \\
Y_4 &= -0.5 = B_0 + 3\,B_1 + 0\,B_2 + E_4 \\
Y_5 &= 5.7 = \alpha_0 + 0\,\alpha_1 + 1\,\alpha_2 + E_5 \\
Y_6 &= 7.5 = \alpha_0 + 0\,\alpha_1 + 3\,\alpha_2 + E_6 \\
Y_7 &= 3.2 = \alpha_0 + 3\,\alpha_1 + 2\,\alpha_2 + E_7 \\
Y_8 &= 1.9 = \alpha_0 + 3\,\alpha_1 + 0\,\alpha_2 + E_8
\end{aligned}$$

$$\text{or} \begin{bmatrix} 4.4 \\ 6.8 \\ 2.9 \\ -0.5 \\ 5.7 \\ 7.5 \\ 3.2 \\ 1.9 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 3 & 0 & 0 & 0 \\ 1 & 3 & 2 & 0 & 0 & 0 \\ 1 & 3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 3 \\ 0 & 0 & 0 & 1 & 3 & 2 \\ 0 & 0 & 0 & 1 & 3 & 0 \end{bmatrix} \begin{bmatrix} B_0 \\ B_1 \\ B_2 \\ \alpha_0 \\ \alpha_1 \\ \alpha_2 \end{bmatrix} + \begin{bmatrix} E_1 \\ E_2 \\ E_3 \\ E_4 \\ E_5 \\ E_6 \\ E_7 \\ E_8 \end{bmatrix} .$$

$$\text{Then} \quad \mathbf{X}'\mathbf{X} = \begin{bmatrix} 4 & 6 & 6 & 0 & 0 & 0 \\ 6 & 18 & 6 & 0 & 0 & 0 \\ 6 & 6 & 14 & 0 & 0 & 0 \\ 0 & 0 & 0 & 4 & 6 & 6 \\ 0 & 0 & 0 & 6 & 18 & 6 \\ 0 & 0 & 0 & 6 & 6 & 14 \end{bmatrix}, \quad \mathbf{X}'\underline{\mathbf{Y}} = \begin{bmatrix} 13.6 \\ 7.2 \\ 30.6 \\ 18.3 \\ 15.3 \\ 34.6 \end{bmatrix} ,$$

$$= (\mathbf{X}'\mathbf{X})^{-1}(\mathbf{X}'\underline{\mathbf{Y}}) = \begin{bmatrix} 1.50000 & -.33333 & -.50000 & 0 & 0 & 0 \\ -.33333 & .13889 & .08333 & 0 & 0 & 0 \\ -.50000 & .08333 & .25000 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1.50000 & -.33333 & -.50000 \\ 0 & 0 & 0 & -.33333 & .13889 & .08333 \\ 0 & 0 & 0 & -.50000 & .08333 & .25000 \end{bmatrix} \begin{bmatrix} 13.6 \\ 7.2 \\ 30.6 \\ 18.3 \\ 15.3 \\ 34.6 \end{bmatrix}$$

$$= \begin{bmatrix} 2.7000 \\ -.9834 \\ 1.4500 \\ 5.0501 \\ -1.0917 \\ .7749 \end{bmatrix} ,$$

$$\begin{aligned} SSE &= \Sigma Y_i^2 - \underline{\hat{\mathbf{B}}}'(\mathbf{X}'\underline{\mathbf{Y}}) \\ &= 176.850 - 176.535 \\ &= .315 \quad ; \end{aligned}$$

and, since six parameters have been estimated, SSE has

$$f = n-6 = 8-6 = 2$$

degrees of freedom. It is important for more general application to recognize SSE as the pooled residual sums of squares from separate regressions; i.e., the proceeding is exactly equivalent to fitting multiple regression equations to the two groups separately and then adding the two residual sums of squares. Similarly, f is the pooled error degrees of freedom.

In this example we have in mind the following hypothesis (following example 4.8). Suppose the researcher suspects that the overall level of response may have changed between the two groups (or suppose he is not concerned with such a change if it does occur), and so suppose that he wishes to test the hypothesis that the slope coefficients only are the same in the two groups and, in fact, are complementary in the sense defined above. This hypothesis can be written

$$H_0 : \begin{array}{l} \alpha_1 = B_1 \\ \alpha_2 = B_2 \\ B_2 = -B_1 \end{array} .$$

When H_0 is included in the model, $\underline{Y} = X^* \underline{B}^* + \underline{E}^*$ is

$$\begin{bmatrix} 4.4 \\ 6.8 \\ 2.9 \\ -0.5 \\ 5.7 \\ 7.5 \\ 3.2 \\ 1.9 \end{bmatrix} = \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -3 \\ 1 & 0 & 1 \\ 1 & 0 & 3 \\ 0 & 1 & -1 \\ 0 & 1 & -3 \\ 0 & 1 & 1 \\ 0 & 1 & 3 \end{bmatrix} \begin{bmatrix} B_0 \\ \alpha_0 \\ B_1 \end{bmatrix} + \begin{bmatrix} E_1^* \\ E_2^* \\ E_3^* \\ E_4^* \\ E_5^* \\ E_6^* \\ E_7^* \\ E_8^* \end{bmatrix}$$

and $$\mathbf{X}^{*\prime}\mathbf{X}^{*} = \begin{bmatrix} 4 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 40 \end{bmatrix}, \quad \mathbf{X}^{*\prime}\underline{\mathbf{Y}} = \begin{bmatrix} 13.6 \\ 18.3 \\ -42.7 \end{bmatrix},$$

$$\underline{\hat{\mathbf{B}}}^{*} = (\mathbf{X}^{*\prime}\mathbf{X}^{*})^{-1}(\mathbf{X}^{*\prime}\underline{\mathbf{Y}}) = \begin{bmatrix} 0.250 & 0 & 0 \\ 0 & 0.250 & 0 \\ 0 & 0 & 0.025 \end{bmatrix} \begin{bmatrix} 13.6 \\ 18.3 \\ -42.7 \end{bmatrix} = \begin{bmatrix} 3.4000 \\ 4.5750 \\ -1.0675 \end{bmatrix},$$

$$\begin{aligned} SSE^{*} &= \Sigma Y_i^{2} - \underline{\hat{\mathbf{B}}}^{*\prime}(\mathbf{X}^{*\prime}\underline{\mathbf{Y}}) \\ &= 176.85 - \begin{bmatrix} 3.4000 & 4.5750 & -1.0675 \end{bmatrix} \begin{bmatrix} 13.6 \\ 18.3 \\ -42.7 \end{bmatrix} \\ &= 1.305 \ ; \end{aligned}$$

and, since three parameters have been estimated, SSE* has

$$f^{*} = n-3 = 8-3 = 5$$

degrees of freedom. Finally,

$$\begin{aligned} F &= \frac{f}{(f^{*} - f)} \cdot \frac{(SSE^{*} - SSE)}{SSE} = \frac{2}{(5 - 2)} \cdot \frac{(1.305 - .315)}{.315} \\ &= 2.10 \end{aligned}$$

and H_0 is not rejected. The data are compatible with the hypothesis.

5. CONCLUDING REMARKS

Clearly, additional examples could be given but the foregoing can be modified so that the general domain of the illustrated test procedure will be apparent. For example, the hypothesis $H_0 : \mu_1 - \mu_2 = 0$ of example 4.1 is easily modified to $H_0 : \mu_1 - \mu_2 = d$ where d is a specified number if the researcher wishes to test the hypothesis that the difference between μ_1 and μ_2 is some quantity other than zero. The corresponding "t" statistic is

$$t = \frac{\bar{Y}_1 - \bar{Y}_2 - d}{s\sqrt{1/n_1 + 1/n_2}} \ .$$

In example 4.2, H_0 could obviously be revised to $H_0 : \mu_1 = a_1$ and $\mu_2 = a_2$ where both a_1 and a_2 are specified but different from each other. In these as well as in all the other examples, the test procedure (3.5) is not affected by imbalance in the number of observations so long as the assumption regarding the independence of the columns of $\mathbf{X}$ holds.

Examples 4.3 and 4.4 suggest methodology for testing hypotheses that the response to several imposed treatments is an arithmetic and geometric progression, respectively. Thus, in general, if the original model $\underline{\mathbf{Y}} = \mathbf{X}\,\underline{\mathbf{B}} + \underline{\mathbf{E}}$ contains p parameters, $\tau_1, \tau_2, \cdots, \tau_p$, representing the added effect of p ordered treatments or treatment levels, then clearly the hypothesis that response is an arithmetic progression with specified common difference d can be written

$$H_0 : \begin{array}{l} \tau_2 = \tau_1 + d \\ \tau_3 = \tau_1 + 2d \\ \cdots \quad \cdots \quad \cdots \\ \tau_m = \tau_1 + (m-1)d \end{array} \qquad \text{or} \qquad \begin{array}{l} \tau_2 - \tau_1 = d \\ \tau_3 - \tau_1 = 2d \\ \cdots \quad \cdots \quad \cdots \\ \tau_m - \tau_1 = (m-1)d \end{array}$$

and, since this is of the form (2.3), the procedure (3.5) applies. Similarly, if the hypothesis is that the response is a geometric progression with specified common ratio, r, then it can be written

$$H_0 : \begin{array}{l} \tau_2 = r\,\tau_1 \\ \tau_3 = r^2\,\tau_1 \\ \cdots \quad \cdots \\ \tau_m = r^{(m-1)}\,\tau_1 \end{array} \qquad \text{or} \qquad \begin{array}{l} \tau_2 - r\,\tau_1 = 0 \\ \tau_3 - r^2\,\tau_1 = 0 \\ \cdots \quad \cdots \quad \cdots \\ \tau_m - r^{(m-1)}\,\tau_1 = 0 \end{array}$$

which is of the form (2.3).

In example 4.7, if the hypothesis is that a subset of the B's has true values zero, then the procedure (3.5) is essentially the traditional one. {cf. Anderson and Bancroft [2] p. 172} .

If the hypothesis in example 4.9 is changed to

$$H : \begin{array}{l} \alpha_0 = B_0 \\ \alpha_1 = B_1 \\ \alpha_2 = B_2 \end{array} ,$$

then the resulting F test is a test of the hypothesis that the two groups share a common regression.

And so on.

6. APPENDIX

A matrix is a rectangular array of positioned numbers[9/]. Thus,

$$\mathbf{A} = \begin{bmatrix} 11 & 12 \\ 21 & 22 \end{bmatrix} \text{ and } \mathbf{B} = \begin{bmatrix} 12 & 11 \\ 21 & 22 \end{bmatrix}$$

are matrices. Matrices in this paper are denoted by boldface lettering.

The dimensions of a matrix are the number of rows x the number of columns. Thus, $\mathbf{A}$ and $\mathbf{B}$ above are both 2 x 2 matrices.

Two matrices are equal if and only if they have the same dimensions and equal numbers in corresponding positions. Thus, $\mathbf{A}$ and $\mathbf{B}$ above are not equal; i.e., $\mathbf{A} \neq \mathbf{B}$.

The transpose of the matrix $\mathbf{A}$, denoted by $\mathbf{A}'$, is obtained from $\mathbf{A}$ by interchanging the role of rows and columns. Thus, if

$$\mathbf{A} = \begin{bmatrix} 11 & 12 & 13 \\ 21 & 22 & 23 \end{bmatrix}, \text{ then } \mathbf{A}' = \begin{bmatrix} 11 & 21 \\ 12 & 22 \\ 13 & 23 \end{bmatrix} .$$

[9/] Here we assume that these numbers are real.

A column vector is a matrix with one column. Thus, for example,

$$\mathbf{Y} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} .$$

A row vector is a matrix with one row. Thus, for example,

$$\mathbf{Y}' = \begin{bmatrix} Y_1 & Y_2 & Y_3 \end{bmatrix} .$$

If $\mathbf{A}$ and $\mathbf{B}$ have the same dimensions, their sum, $\mathbf{A} + \mathbf{B}$, is obtained by adding elements in corresponding positions, for example,

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} + \begin{bmatrix} 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} = \begin{bmatrix} 5 & 7 & 9 \\ 11 & 13 & 15 \end{bmatrix} .$$

If $\mathbf{A}$ and $\mathbf{B}$ do not have the same dimensions, their sum is not defined.

If $\mathbf{A}$ is a matrix and k a number or scaler, then the scaler product $k\mathbf{A} = \mathbf{A}k$ is obtained from $\mathbf{A}$ by multiplying each element of $\mathbf{A}$ by the number k.

If $\mathbf{A}$ and $\mathbf{B}$ have the same dimensions, then the difference $\mathbf{A} - \mathbf{B}$ is defined as $\mathbf{A} + (-1)\mathbf{B}$. Otherwise $\mathbf{A} - \mathbf{B}$ is not defined.

If $\mathbf{A}$ is an $n \times m$ matrix and $\mathbf{B}$ is an $m \times p$ matrix, then the matrix product $\mathbf{AB} = \mathbf{C}$ where $\mathbf{C}$ is an $n \times p$ matrix, is defined as follows. The element in row i $(i = 1, 2, \ldots, n)$ and column j $(j = 1, 2, \ldots, p)$ of $\mathbf{C}$ is the element-by-element product of the i^{th} row of $\mathbf{A}$ by the j^{th} column of $\mathbf{B}$. For example,

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} \begin{bmatrix} 1 & 4 \\ 2 & 5 \\ 3 & 6 \end{bmatrix} = \begin{bmatrix} (1)(1)+(2)(2)+(3)(3) & (1)(4)+(2)(5)+(3)(6) \\ (4)(1)+(5)(2)+(6)(3) & (4)(4)+(5)(5)+(6)(6) \end{bmatrix}$$

$$= \begin{bmatrix} 14 & 32 \\ 32 & 77 \end{bmatrix} .$$

If the number of columns of $\mathbf{A}$ and the number of rows of $\mathbf{B}$ are not the same, then $\mathbf{AB}$ is not defined. Note that matrix multiplication is not commutative; i.e., $\mathbf{AB}$ does not equal $\mathbf{BA}$ necessarily, even if both products are defined. For example, reversing the order of multiplication of the two matrices immediately above yields

$$\begin{bmatrix} 1 & 4 \\ 2 & 5 \\ 3 & 6 \end{bmatrix} \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} = \begin{bmatrix} 17 & 22 & 27 \\ 22 & 29 & 36 \\ 27 & 36 & 45 \end{bmatrix} .$$

A square matrix (i.e., a matrix with dimensions n x n) of the form

$$\begin{bmatrix} 1 & 0 & \cdots & 0 \\ 0 & 1 & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & \cdots & 1 \end{bmatrix}$$

is called the identity matrix and conventionally denoted by $\mathbf{I}$ (occasionally subscripted to indicate the dimensions thus $\mathbf{I}_n$). $\mathbf{I}$ is more precisely the multiplicative identity; i.e., for any matrix $\mathbf{A}$ with n rows and m columns

$$\mathbf{I}_n \mathbf{A} = \mathbf{A} \mathbf{I}_m = \mathbf{A} .$$

For example,

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} .$$

If A is a square matrix, then the inverse of A, if it exists, is a uniquely determined matrix, conventionally denoted by A^{-1}, such that

$$AA^{-1} = A^{-1}A = I.$$

For example,

$$A = \begin{bmatrix} 1 & 2 \\ 2 & 3 \end{bmatrix} \text{ implies that } A^{-1} = \begin{bmatrix} -3 & 2 \\ 2 & -1 \end{bmatrix}$$

since $\begin{bmatrix} 1 & 2 \\ 2 & 3 \end{bmatrix} \begin{bmatrix} -3 & 2 \\ 2 & -1 \end{bmatrix} = \begin{bmatrix} -3 & 2 \\ 2 & -1 \end{bmatrix} \begin{bmatrix} 1 & 2 \\ 2 & 3 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$,

whereas if $B = \begin{bmatrix} 1 & 2 \\ 2 & 4 \end{bmatrix}$, then B^{-1} does not exist; i.e., for every 2 x 2 matrix C it is not true that $BC = CB = I$.

The concept of the (multiplicative) inverse plays a more prominent role in matrix algebra than in ordinary algebra since the quotient of two matrices is not defined. Thus, in ordinary algebra the quotient, a/b, of two real numbers a and b $(b \neq 0)$ is defined as

$$a/b = a \cdot b^{-1}$$

where b^{-1} is the multiplicative inverse of b. In matrix algebra, multiplication by inverses is retained in lieu of division. The following concepts assist in determining whether specific members of an important class of matrices have inverses; viz, those of the form $(X'X)$.

A partitioned matrix, X, of dimensions n x m is a matrix within which smaller matrices have been delineated by the use of partitions in the ordinary sense of the word. Thus,

$$X = \begin{bmatrix} 11 & 12 \\ 21 & 22 \end{bmatrix}$$

can be partitioned into two column vectors, or into two row vectors, or into 4 scalers.

Suppose now that X is an n x m matrix and partition it into m column vectors $\underline{X}_i$, i = 1, 2, ... , m, of n elements each as follows

$$X = \begin{bmatrix} X_{11} & \vdots & X_{21} & \vdots & \cdots & \vdots & X_{m1} \\ X_{12} & \vdots & X_{22} & \vdots & \cdots & \vdots & X_{m2} \\ \cdots & \vdots & \cdots & \vdots & \cdots & \vdots & \cdots \\ X_{1n} & \vdots & X_{2n} & \vdots & \cdots & \vdots & X_{mn} \end{bmatrix} = \begin{bmatrix} \underline{X}_1 & \underline{X}_2 & \cdots & \underline{X}_m \end{bmatrix} .$$

If any one of the column vectors can be written as a linear combination of the others, then the column vectors of X are said to be linearly dependent; i.e., if the set is linearly dependent, at least one of the vectors, say $\underline{X}_j$, can be written

$$\underline{X}_j = k_1 \underline{X}_1 + k_2 \underline{X}_2 + \cdots + k_{j-1} \underline{X}_{j-1} + k_{j+1} \underline{X}_{j+1} + \cdots k_m \underline{X}_m$$

where the k's are numbers (perhaps zero). Otherwise the column vectors are said to be linearly independent.

Consider the following examples.

First, suppose X is the identity matrix with dimensions 3 x 3; i.e.,

$$X = \begin{bmatrix} 1 & \vdots & 0 & \vdots & 0 \\ 0 & \vdots & 1 & \vdots & 0 \\ 0 & \vdots & 0 & \vdots & 1 \end{bmatrix} \quad \text{so } \underline{X}_1 = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}, \ \underline{X}_2 = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}, \text{and } \underline{X}_3 = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} .$$

Clearly $\underline{X}_1$ cannot be expressed as a linear combination of $\underline{X}_2$ and $\underline{X}_3$ since

$$k_2 \underline{X}_2 + k_3 \underline{X}_3 = \begin{bmatrix} 0 \\ k_2 \\ k_3 \end{bmatrix} \neq \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

no matter how k_2 and k_3 are chosen. Similarly, $\underline{X}_2$ and $\underline{X}_3$ cannot be expressed as linear combinations of the remaining vectors and hence the columns of the identity matrix I_3 are linearly independent.

If, however,

$$\mathbf{X} = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 \end{bmatrix} ,$$

then $\underline{\mathbf{X}}_1 = \underline{\mathbf{X}}_2 + \underline{\mathbf{X}}_3 + \underline{\mathbf{X}}_4$ and the columns of $\mathbf{X}$ are linearly dependent.

The following theorem has large practical utility.

If the columns of $\mathbf{X}$ are linearly independent, then $(\mathbf{X}'\mathbf{X})$ has an inverse and vice versa.

In introducing example 4.3 in the text, the difficulties that accompany the linear dependency of the columns of the matrix $\mathbf{X}$ in the linear model $\underline{\mathbf{Y}} = \mathbf{X}\underline{\mathbf{B}} + \underline{\mathbf{E}}$ are briefly described. The theorem above indicates that these difficulties are reflected in the manipulation of the relevant matrices by the fact that the inverse required for a unique determination of the least squares estimate of $\underline{\mathbf{B}}$ does not exist.

In many practical applications of the methodology of the text, the linear dependence described here can be detected (when it occurs) by inspection, but methods for systematically demonstrating independence requires additional theory that will not be given. A general treatment of determinants and matrices that emphasizes the phylogeny of matrix algebra is that by Aitken [1].

These are the concepts from matrix algebra that have been used in the text. Hopefully, their utility in dealing with systems of simultaneous equations will quickly be evident. For example, it should be easy to see, even with only this brief acquaintance with this algebra, that if $\mathbf{A}$ is a matrix of known numbers, with an inverse, $\mathbf{A}^{-1}$, and if $\underline{\mathbf{B}}$ is a column vector of known numbers and if $\underline{\mathbf{X}}$ is a column vector of unknown variables, then the solution of the system of simultaneous equations $\mathbf{A}\underline{\mathbf{X}} = \underline{\mathbf{B}}$ is given by $\underline{\mathbf{X}} = \mathbf{A}^{-1}\underline{\mathbf{B}}$. This is the matrix analogue of the solution of $ax = b$ $(a \neq 0)$ which is $x = a^{-1}b = b/a$.

Methodology for systematically computing the inverse of a matrix is given by Anderson and Bancroft [2], by Snedecor [5], and by Steel and Torrie [6].

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Swindel, Benee F.
1970. Some Applications of the Principle of Conditional Error. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-59, 48 pp.

The principle of conditional error is an elegant computational procedure very often useful in statistical tests of hypotheses. This paper gives an elementary discussion of the principle and nine numerical examples (with discussion) chosen to illustrate the wide applicability of the technique. An acquaintance with the analytical procedures of analysis of variance, analysis of covariance, and regression analysis is assumed.

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Yields and Stand Structural Patterns for Old-Field Plantations of Slash Pine

by

Frank A. Bennett

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Yields and Stand Structural Patterns for Old-Field Plantations of Slash Pine

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Yield estimates for slash pine plantations have been available since 1955, when yield tables for Florida plantations were published by Barnes.[1] Since then tables have been developed for other areas and they have all filled a need in the management programs of these stands. However, as useful as these tables have been and may be, they do not provide detailed information on stand structure as influenced by age, site, and stand density. For example, all the yield studies indicate an almost continuous increase in cordwood volume as number of trees per acre is increased, but little information is given on tree sizes (other than average d.b.h.) or the number of trees that may be below the minimum merchantable size at given ages. This information is necessary for the most efficient management planning. Increased yields from the denser stands may be more than offset by increased cost of harvesting the smaller tree sizes. Some logging cost records indicate 5- and 6-inch trees are submarginal or at best marginal. Stands with a high proportion of these sizes do not attract good stumpage prices, and some knowledge on diameter ranges in these plantations would be invaluable in management programing.

Estimating multiple-product yields has been a particularly difficult problem because of the lack of information on diameter distributions. This problem has been alleviated by the recent publication of diameter distributions for old-field slash pine plantations.[2] [3] The distributional data permitted the estimating of pulpwood, sawtimber, and gum yields, individually or in any combination of the three products. However, diameter distributions, estimated yields, and return values were published for only five different ages--10, 15, 20, 25, and 30. Reliable wood and gum yields can be easily established by interpolation for the years not covered by the yield table, but interpolation of diameter distribution frequencies requires much more work.

---

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To further help the forest manager plan and rationalize his management programs, especially with respect to multiple-product aspects, this paper includes diameter distributional patterns, with associated wood, gum, and basal area yields by 2-year intervals (table 1). Also included are estimates of number of pulpwood bolts by diameter class and per acre (table 2, page 81). Although tree-length logging and chipping to some extent reduce the need for bolt information, mechanical harvesters and thinners still produce wood in bolt form. Having an estimate of the number of bolts per acre and per cord will be quite useful in establishing cost-benefit ratios for these machines and for overall management programs.

Data for densities greater than 500 trees per acre beyond age 20 and for densities greater than 300 trees beyond age 25 are extrapolated and should be viewed and used accordingly. Although less reliable than estimates within the range of the sample data, the extrapolated values can serve as a guide to what might be expected for the higher densities at the older ages. Nevertheless, there is a point beyond which extrapolation may become misleading.

A factor of 92 cubic feet of wood and bark per standard cord was used to convert cubic feet to cords in table 1. Also, the computer calculated to a fraction of a tree for the number of trees per diameter class. Rounding to the nearest whole number causes the total number of trees per acre to deviate by one or two trees from the indicated density class in some instances. The cubic-volume yield under multiple products includes nonsawtimber trees and topwood volume for the sawtimber trees.

The range of the sample data did not permit calculation of predicted values for densities of 600, 700, and 800 trees per acre for ages 10 and 12 on sites 50 and 60 nor for 700 and 800 trees per acre at age 12 on site 50.

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies

e: 10   Site index: 50 (25-year basis)   Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	15	0	0	0	0	0	0.1
30	18	0	0	0	0	0	2.6
77	20	25	0.3	154	0	0	10.5
77	22	83	0.9	192	0	0	15.1
14	23	29	0.3	41	0	0	3.8
200	--	137	1.5	387	0	0	32.1

Age: 10   Site index: 50 (25-year basis)   Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	26	15	0	0	0	0	0	1.3
4	100	18	0	0	0	0	0	8.7
5	127	21	45	0.5	258	0	0	17.3
6	47	22	53	0.6	120	0	0	9.2
7								
8								
9								
10								
11								
12								
13								
14								
15								
Totals	300	--	98	1.1	378	0	0	36.5

: 10   Site index: 50 (25-year basis)   Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
6	11	0	0	0	0	0	0.1
78	16	0	0	0	0	0	3.8
165	19	0	0	0	0	0	14.4
131	21	50	0.5	271	0	0	17.9
20	23	24	0.3	53	0	0	4.0
400	--	74	0.8	324	0	0	40.2

Age: 10   Site index: 50 (25-year basis)   Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	26	11	0	0	0	0	0	0.6
3	139	16	0	0	0	0	0	6.8
4	206	19	0	0	0	0	0	17.9
5	119	22	49	0.5	250	0	0	16.2
6	10	23	13	0.1	28	0	0	2.0
7								
8								
9								
10								
11								
12								
13								
14								
15								
Totals	500	--	62	0.6	278	0	0	43.5

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 12 Site index: 50 (25-year basis) Density class: 200

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal [redacted]
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	18	0	0	0	0	0	0
4	14	22	0	0	0	0	0	1.2
5	42	24	25	0.3	98	0	0	5.8
6	67	26	100	1.1	198	0	0	13.1
7	60	28	157	1.7	206	0	0	16.0
8	17	29	66	0.7	64	0	0	5.9
9								
10								
11								
12								
13								
14								
15								
Totals	201	--	348	3.8	566	0	0	42.0

Age: 12 Site index: 50 (25-year basis) Densi

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple pro
			Volume		5.25-foot bolts	Saw-timber
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.
1						
2						
3	11	18	0	0	0	0
4	54	22	0	0	0	0
5	97	25	61	0.7	228	0
6	98	27	152	1.7	295	0
7	40	28	108	1.2	140	0
8						
9						
10						
11						
12						
13						
14						
15						
Totals	300	--	321	3.6	663	0

Age: 12 Site index: 50 (25-year basis) Density class: 400

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	[illegible]	13	0	0	0	0	0	0.1
3	39	19	0	0	0	0	0	1.9
4	106	23	0	0	0	0	0	9.2
5	139	25	93	1.0	332	0	0	19.0
6	96	27	156	1.7	298	0	0	18.9
7	17	29	46	0.5	59	0	0	4.4
8								
9								
10								
11								
12								
13								
14								
15								
Totals	400	--	295	3.2	689	0	0	53.5

Age: 12 Site index: 50 (25-year basis) Densi

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple pro
			Volume		5.25-foot bolts	Saw-timber
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.
1						
2	12	13	0	0	0	0
3	80	19	0	0	0	0
4	156	23	0	0	0	0
5	163	26	115	1.3	395	0
6	83	28	139	1.5	261	0
7	7	30	19	0.2	25	0
8						
9						
10						
11						
12						
13						
14						
15						
Totals	501	--	273	3.0	681	0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 12 Site index: 50 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	1	4	0	0	0	0	0	0
2	31	13	0	0	0	0	0	0.7
3	125	20	0	0	0	0	0	6.1
4	197	24	0	0	0	0	0	17.2
5	173	26	129	1.4	427	0	0	23.6
6	70	29	122	1.3	225	0	0	13.7
7	3	30	10	0.1	13	0	0	0.9
8								
9								
10								
11								
12								
13								
14								
15								
Totals	600	--	261	2.8	665	0	0	62.2

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 14 Site index: 50 (25-year basis) Density class: 200

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	8	25	0	0	0	0	0	0.7
5	28	28	24	0.2	71	0	0	3.8
6	50	30	92	1.0	167	0	0	9.8
7	60	32	188	2.0	236	0	0	16.0
8	45	[illegible]	207	2.2	194	0	0	15.6
9	9	34	58	0.6	42	0	0	4.0
10								
11								
12								
13								
14								
15								
Totals	200	--	569	6.0	710	0	0	49.9

Age: 14 Site index: 50 (25-year basis) Density clas

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	7	21	0	0	0	0	0
4	34	25	0	0	0	0	0
5	72	28	62	0.7	186	0	0
6	92	30	177	1.9	314	0	0
7	74	32	237	2.6	296	0	0
8	22	34	102	1.1	96	0	0
9							
10							
11							
12							
13							
14							
15							
Totals	301	--	578	6.3	892	0	0

Age: 14 Site index: 50 (25-year basis) Density class: 400

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	2	14	0	0	0	0	0	0
3	25	21	0	0	0	0	0	1.2
4	74	26	0	0	0	0	0	6.5
5	117	29	106	1.1	117	0	0	15.9
6	116	31	231	2.5	404	0	0	22.8
7	62	33	205	2.2	253	0	0	16.5
8	5	34	25	0.3	24	0	0	1.8
9								
10								
11								
12								
13								
14								
15								
Totals	401	--	567	6.1	798	0	0	64.7

Age: 14 Site index: 50 (25-year basis) Density cl

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2	8	15	0	0	0	0	0
3	53	22	0	0	0	0	0
4	118	26	0	0	0	0	0
5	153	30	145	1.6	412	0	0
6	123	32	253	2.7	437	0	0
7	44	34	151	1.6	186	0	0
8	1	35	4	0	4	0	0
9							
10							
11							
12							
13							
14							
15							
Totals	500	--	553	5.9	1,039	0	0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 14 Site index: 50 (25-year basis) Density class: 600

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
20	15	0	0	0	0	0	0.4
89	22	0	0	0	0	0	4.3
161	27	0	0	0	0	0	14.0
179	30	178	1.9	491	0	0	24.4
120	33	256	2.8	437	0	0	23.6
31	34	109	1.2	133	0	0	8.3
600	--	543	5.9	1,061	0	0	75.0

Age: 14 Site index: 50 (25-year basis) Density class: 700

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	2	5	0	0	0	0	0	0
2	39	16	0	0	0	0	0	0.9
3	127	25	0	0	0	0	0	6.2
4	199	28	0	0	0	0	0	17.4
5	196	31	204	2.2	548	0	0	26.7
6	114	33	252	2.7	424	0	0	22.5
7	23	35	83	0.9	101	0	0	6.1
8								
9								
10								
11								
12								
13								
14								
15								
Totals	700	--	539	5.8	1,073	0	0	79.8

Age: 14 Site index: 50 (25-year basis) Density class: 800

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	5	5	0	0	0	0	0	0
2	63	16	0	0	0	0	0	1.4
3	166	25	0	0	0	0	0	8.1
4	231	28	0	0	0	0	0	20.2
5	207	32	225	2.4	590	0	0	28.2
6	109	34	247	2.7	412	0	0	21.4
7	19	36	70	0.8	84	0	0	5.0
8								
9								
10								
11								
12								
13								
14								
15								
Totals	800	--	542	5.9	1,086	0	0	84.3

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 16 Site index: 50 (25-year basis) Density class: 200

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	6	27	0	0	0	0	0	0.5
5	20	30	21	0.2	56	0	21	2.8
6	39	33	85	0.9	144	0	85	7.7
7	53	35	189	2.1	229	0	189	14.2
8	51	36	267	2.9	248	0	267	17.9
9	28	37	201	2.2	146	0	201	12.4
10	2	38	16	0.2	9	17	7	0.9
11								
12								
13								
14								
15								
Totals	199	--	779	8.5	832	17	770	56.4

Age: 16 Site index: 50 (25-year basis) Density cla

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	5	23	0	0	0	0	0
4	25	28	0	0	0	0	0
5	56	31	59	0.6	157	0	0
6	80	34	179	1.9	299	0	0
7	80	36	295	3.2	356	0	0
8	48	37	257	2.8	237	0	0
9	6	38	41	0.4	30	0	0
10							
11							
12							
13							
14							
15							
Totals	300	--	831	8.9	1,079	0	0

Age: 16 Site index: 50 (25-year basis) Density class: 400

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	16	0	0	0	0	0	0
3	18	23	0	0	0	0	0	0.9
4	56	28	0	0	0	0	0	4.9
5	97	32	108	1.2	279	0	0	13.2
6	113	34	260	2.8	432	0	0	22.2
7	87	36	326	3.5	392	0	0	23.1
8	28	38	152	1.7	140	0	0	9.7
9								
10								
11								
12								
13								
14								
15								
Totals	400	--	846	9.2	1,243	0	0	74.0

Age: 16 Site index: 50 (25-year basis) Density cla

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2	6	16	0	0	0	0	0
3	40	24	0	0	0	0	0
4	94	29	0	0	0	0	0
5	136	32	157	1.7	397	0	0
6	133	35	317	3.4	519	0	0
7	79	37	305	3.3	365	0	0
8	13	39	71	0.8	65	0	0
9							
10							
11							
12							
13							
14							
15							
Totals	501	--	850	9.2	1,346	0	0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 16 Site index: 50 (25-year basis) Density class: 600

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
15	17	0	0	0	0	0	0.3
68	24	0	0	0	0	0	3.3
134	30	0	0	0	0	0	11.7
168	33	203	2.2	502	0	0	23.0
142	36	350	3.8	567	0	0	28.0
66	38	265	2.9	315	0	0	17.8
6	40	32	0.3	29	0	0	1.9
599	--	850	9.2	1,413	0	0	86.0

Age: 16 Site index: 50 (25-year basis) Density class: 700

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	1	5	0	0	0	0	0	0
2	29	17	0	0	0	0	0	0.6
3	101	25	0	0	0	0	0	5.0
4	172	30	0	0	0	0	0	15.0
5	194	34	243	2.6	588	0	0	26.4
6	145	37	367	4.0	588	0	0	28.4
7	55	39	226	2.5	267	0	0	14.7
8	3	40	15	0.2	14	0	0	0.9
9								
10								
11								
12								
13								
14								
15								
Totals	700	--	851	9.3	1,457	0	0	91.0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 18 Site index: 50 (25-year basis) Density class: 200

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	5	29	0	0	0	0	0	0.4
5	16	[illegible]	19	0.2	48	0	19	2.2
6	32	36	78	0.9	128	0	78	6.4
7	47	37	183	2.0	218	0	183	12.5
8	51	39	290	3.2	265	0	290	17.7
9	38	40	299	3.3	217	0	299	17.0
10	11	41	108	1.2	64	14[illegible]	50	5.8
11								
12								
13								
14								
15								
Totals	200	--	977	10.8	940	14[illegible]	919	62.0

Age: 18 Site index: 50 (25-year basis) Density clas

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	4	25	0	0	0	0	0
4	20	30	0	0	0	0	0
5	46	34	56	0.6	138	0	0
6	70	36	174	1.9	282	0	0
7	79	38	318	3.5	376	0	0
8	61	40	360	3.9	328	0	0
9	20	41	163	1.8	118	0	0
10							
11							
12							
13							
14							
15							
Totals	300	--	1,071	11.7	1,242	0	0

Age: 18 Site index: 50 (25-year basis) Density class: 400

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	17	0	0	0	0	0	0
3	14	25	0	0	0	0	0	0.7
4	46	31	0	0	0	0	0	4.0
5	83	34	106	1.2	254	0	0	11.3
6	106	37	271	2.9	433	0	0	20.7
7	96	39	397	4.3	468	0	0	25.6
8	51	41	305	3.3	278	0	0	17.7
9	4	42	37	0.4	27	0	0	2.0
10								
11								
12								
13								
14								
15								
Totals	401	--	1,116	12.1	1,460	0	0	82.0

Age: 18 Site index: 50 (25-year basis) Density cla

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2	4	18	0	0	0	0	0
3	32	26	0	0	0	0	0
4	79	31	0	0	0	0	0
5	121	35	161	1.7	377	0	0
6	132	38	350	3.8	554	0	0
7	98	40	420	4.6	492	0	0
8	33	42	207	2.2	187	0	0
9							
10							
11							
12							
13							
14							
15							
Totals	499	--	1,138	12.3	1,610	0	0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 18 Site index: 50 (25-year basis) Density class: 600

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
12	18	0	0	0	0	0	0.3
56	26	0	0	0	0	0	2.7
115	32	0	0	0	0	0	10.0
156	36	215	2.3	495	0	0	21.2
150	39	409	4.4	641	0	0	29.4
92	41	406	4.4	472	0	0	24.7
20	43	126	1.4	114	0	0	6.9
601	--	1,156	12.5	1,722	0	0	95.2

Age: 18 Site index: 50 (25-year basis) Density class: 700

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	1	6	0	0	0	0	0	0
2	24	18	0	0	0	0	0	0.5
3	84	27	0	0	0	0	0	4.1
4	152	33	0	0	0	0	0	13.2
5	185	37	266	2.9	600	0	0	25.3
6	160	40	449	4.9	696	0	0	31.3
7	83	42	375	4.1	436	0	0	22.3
8	12	44	77	0.8	69	0	0	4.1
9								
10								
11								
12								
13								
14								
15								
Totals	701	--	1,167	12.7	1,801	0	0	100.8

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 20 Site index: 50 (25-year basis) Density class: 200

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	[illegible]	1	0	0	0	0	0	0.3
5	14	[illegible]	18	0.2	42	0	18	1.8
6	28	38	[illegible]	0.8	116	0	73	5.5
7	42	40	176	1.9	207	0	176	11.1
8	49	42	298	3.2	271	0	298	17.0
9	[illegible]	[illegible]	355	3.9	257	0	355	18.8
10	21	44	228	2.5	134	[illegible]	106	11.5
11	1	45	10	0.1	5	24	3	0.5
12								
13								
14								
15								
Totals	202	--	1,158	12.6	1,032	365	1,029	66.5

Age: 20 Site index: 50 (25-year basis) Density class

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	3	26	0	0	[illegible]	0	0
4	16	32	0	0	0	0	0
5	39	36	54	0.6	124	0	54
6	62	38	169	1.8	265	0	169
7	75	41	326	3.5	380	0	326
8	67	42	421	4.6	382	0	421
9	35	44	298	3.2	216	0	298
10	2	45	26	0.3	16	41	12
11							
12							
13							
14							
15							
Totals	299	--	1,294	14.0	1,383	41	1,280

Age: 20 Site index: 50 (25-year basis) Density class: 400

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	18	0	0	0	0	0	0
3	11	27	0	0	0	0	0	0.6
4	[illegible]	[illegible]	0	0	0	0	0	[illegible]
5	73	36	104	1.1	234	0	0	9.9
6	98	39	273	3.0	424	0	0	19.2
7	98	42	438	4.8	509	0	0	26.2
8	66	43	425	4.6	385	0	0	23.0
9	15	45	132	1.4	95	0	0	6.6
10								
11								
12								
13								
14								
15								
Totals	401	--	1,372	14.9	1,647	0	0	88.9

Age: 20 Site index: 50 (25-year basis) Density cla

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2	4	19	0	0	0	0	0
3	26	28	0	0	0	0	0
4	68	33	0	0	0	0	0
5	109	37	161	1.8	358	0	0
6	128	40	368	4.0	567	0	0
7	108	43	499	5.4	577	0	[illegible]
8	53	44	352	3.8	317	0	0
9	4	46	37	0.4	27	0	0
10							
11							
12							
13							
14							
15							
Totals	500	--	1,417	15.4	1,846	0	0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 20 Site index: 50 (25-year basis) Density class: 600

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
10	19	0	0	0	0	0	0.2
47	28	0	0	0	0	0	2.3
101	34	0	0	0	0	0	8.8
144	38	221	2.4	482	0	0	19.6
150	41	447	4.9	682	0	0	29.5
109	44	516	5.6	593	0	0	29.2
38	45	259	2.8	233	0	0	13.3
1	47	6	0.1	4	0	0	0.3
600	--	1,449	15.8	1,994	0	0	103.2

Age: 20 Site index: 50 (25-year basis) Density class: 700

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	1	6	0	0	0	0	0	0
2	20	20	0	0	0	0	0	0.4
3	72	29	0	0	0	0	0	3.5
4	136	35	0	0	0	0	0	11.8
5	176	39	280	3.0	599	0	0	23.9
6	166	42	507	5.5	767	0	0	32.6
7	104	44	506	5.5	578	0	0	27.8
8	26	46	182	2.0	163	0	0	9.1
9								
10								
11								
12								
13								
14								
15								
Totals	701	--	1,475	16.0	2,107	0	0	109.1

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 22 Site index: 50 (25-year basis) Density class: 200

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	[illegible]	[illegible]	0	0	0	0	0	0.3
5	12	37	17	0.2	[illegible]	0	17	1.6
6	25	40	69	0.8	107	0	69	4.8
7	[illegible]	42	170	1.9	[illegible]	0	170	10.1
8	46	44	300	3.3	271	0	300	16.1
9	44	45	388	4.2	281	0	388	19.5
10	28	46	321	3.5	190	523	150	15.3
11	4	47	62	0.7	30	147	18	2.8
12								
13								
14								
15								
Totals	200	--	1,327	14.6	1,114	670	1,112	70.5

Age: 22 Site index: 50 (25-year basis) Density clas

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	2	28	0	0	0	0	0
4	14	33	0	0	0	0	0
5	34	38	51	0.6	113	0	51
6	56	40	163	1.8	251	0	163
7	71	43	328	3.6	379	0	328
8	69	45	458	5.0	413	0	458
9	45	46	403	4.4	291	0	403
10	8	47	97	1.1	57	164	45
11							
12							
13							
14							
15							
Totals	299	--	1,500	16.5	1,504	164	1,448

Age: 22 Site index: 50 (25-year basis) Density class: 400

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	19	0	0	0	0	0	0
3	10	28	0	0	0	0	0	0.5
4	34	34	0	0	0	0	0	2.9
5	65	38	101	1.1	219	0	0	8.9
6	91	41	272	3.0	414	0	0	17.8
7	97	44	462	5.0	530	0	0	26.0
8	75	46	512	5.6	460	0	0	26.1
9	28	47	257	2.8	185	0	0	12.3
10								
11								
12								
13								
14								
15								
Totals	401	--	1,604	17.5	1,808	0	0	94.5

Age: 22 Site index: 50 (25-year basis) Density clas

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2	3	20	0	0	0	0	0
3	23	29	0	0	0	0	0
4	60	35	0	0	0	0	0
5	99	39	160	1.7	341	0	0
6	122	42	377	4.1	569	0	0
7	113	45	553	6.0	632	0	0
8	68	47	477	5.2	428	0	0
9	12	48	111	1.2	80	0	0
10							
11							
12							
13							
14							
15							
Totals	500	--	1,678	18.2	2,050	0	0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 22 Site index: 50 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	8	20	0	0	0	0	0	0.2
3	41	30	0	0	0	0	0	2.0
4	90	36	0	0	0	0	0	7.9
5	134	40	223	2.4	468	0	0	18.3
6	148	43	470	5.1	704	0	0	29.1
7	120	46	600	6.5	682	0	0	31.9
8	55	48	396	4.3	353	0	0	19.2
9	4	49	37	0.4	27	0	0	1.7
10								
11								
12								
13								
14								
15								
Totals	600	--	1,726	18.7	2,234	0	0	110.3

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 24 Site index: 50 (25-year basis) Density class: 200

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	[illegible]	34	0	0	0	0	0	0.2
5	10	38	16	0.2	35	0	16	1.4
6	22	41	66	0.7	101	0	66	4.4
7	35	44	165	1.8	189	0	165	9.3
8	44	45	298	3.2	268	0	298	15.3
9	44	47	408	4.4	294	0	408	19.5
10	32	48	388	4.2	229	674	182	17.7
11	9	49	139	1.5	68	344	40	6.1
12								
13								
14								
15								
Totals	199	--	1,480	16.0	1,184	1,018	1,175	73.9

Age: 24 Site index: 50 (25-year basis) Density class

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	2	29	0	0	0	0	0
4	13	35	0	0	0	0	0
5	31	39	49	0.5	106	0	49
6	52	42	159	1.7	240	0	159
7	67	45	327	3.6	374	0	327
8	69	46	482	5.2	431	0	482
9	51	48	481	5.2	347	0	481
10	16	49	194	2.1	114	347	91
11							
12							
13							
14							
15							
Totals	301	--	1,692	18.3	1,612	347	1,589

Age: 24 Site index: 50 (25-year basis) Density class: 400

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	20	0	0	0	0	0	0
3	9	29	0	0	0	0	0	0.4
4	30	36	0	0	0	0	0	2.6
5	59	40	98	1.1	206	0	98	8.1
6	85	43	269	2.9	403	0	269	16.7
7	95	46	476	5.2	542	0	476	25.5
8	80	48	575	6.3	515	0	575	28.0
9	39	49	378	4.1	272	0	378	17.2
10	2	50	28	0.3	16	52	13	1.2
11								
12								
13								
14								
15								
Totals	400	--	1,824	19.9	1,954	52	1,809	99.7

Age: 24 Site index: 50 (25-year basis) Density clas

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2	3	20	0	0	0	0	0
3	20	30	0	0	0	0	0
4	54	36	0	0	0	0	0
5	92	41	158	1.7	326	0	0
6	117	44	381	4.1	566	0	0
7	115	47	590	6.4	668	0	0
8	78	49	577	6.3	516	0	0
9	21	50	211	2.3	152	0	0
10							
11							
12							
13							
14							
15							
Totals	500	--	1,917	20.8	2,228	0	0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 24 Site index: 50 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	7	21	0	0	0	0	0	0.2
3	37	31	0	0	0	0	0	1.8
4	82	37	0	0	0	0	0	7.2
5	126	42	224	2.4	455	0	0	17.1
6	145	45	485	5.3	715	0	0	28.4
7	126	48	662	7.2	748	0	0	33.6
8	69	50	518	5.6	462	0	0	24.0
9	9	51	94	1.0	68	0	0	4.1
10								
11								
12								
13								
14								
15								
Totals	601	--	1,983	21.5	2,448	0	0	116.4

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 26 Site index: 50 (25-year basis) Density class: 200

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	2	35	0	0	0	0	0	0.2
5	10	40	15	0.2	33	0	15	1.3
6	20	43	64	0.7	96	0	64	4.0
7	32	45	160	1.7	182	0	160	8.7
8	42	47	296	3.2	265	0	296	14.5
9	44	49	421	4.6	303	0	421	19.4
10	35	50	437	4.7	258	796	205	19.2
11	14	51	225	2.4	111	575	66	9.5
12								
13								
14								
15								
Totals	199	--	1,618	17.5	1,248	1,371	1,227	76.8

Age: 26 Site index: 50 (25-year basis) Density class:

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	2	30	0	0	0	0	0
4	11	36	0	0	0	0	0
5	28	40	48	0.5	99	0	48
6	48	44	154	1.7	230	0	154
7	64	46	324	3.5	368	0	324
8	68	48	496	5.4	443	0	496
9	55	50	539	5.9	389	0	539
10	23	51	297	3.2	175	556	139
11							
12							
13							
14							
15							
Totals	299	--	1,858	20.2	1,704	556	1,700

Age: 26 Site index: 50 (25-year basis) Density class: 400

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	8	30	0	0	0	0	0	0.4
4	27	37	0	0	0	0	0	2.4
5	55	41	96	1.0	196	0	96	7.5
6	80	45	266	2.9	393	0	266	15.8
7	93	47	484	5.3	547	0	484	24.8
8	83	49	621	6.8	554	0	621	29.0
9	48	51	481	5.2	346	0	481	21.1
10	6	52	78	0.8	46	150	37	3.3
11								
12								
13								
14								
15								
Totals	400	--	2,026	22.0	2,082	150	1,985	104.3

Age: 26 Site index: 50 (25-year basis) Density class:

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2	2	21	0	0	0	0	0
3	18	31	0	0	0	0	0
4	49	38	0	0	0	0	0
5	86	42	156	1.7	313	0	0
6	112	46	382	4.2	562	0	0
7	115	48	616	6.7	694	0	0
8	86	50	657	7.1	585	0	0
9	31	52	323	3.5	232	0	0
10							
11							
12							
13							
14							
15							
Totals	499	--	2,134	23.2	2,386	0	0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 26   Site index: 50 (25-year basis)   Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	7	22	0	0	0	0	0	0.1
3	33	32	0	0	0	0	0	1.6
4	76	39	0	0	0	0	0	6.6
5	118	43	223	2.4	442	0	0	16.1
6	141	47	495	5.4	720	0	0	27.7
7	129	49	710	7.7	796	0	0	34.5
8	79	51	624	6.8	554	0	0	27.7
9	16	53	172	1.9	123	0	0	7.2
10								
11								
12								
13								
14								
15								
Totals	599	--	2,224	24.2	2,635	0	0	121.5

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 28 Site index: 50 (25-year basis) Density class: 200

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	2	36	0	0	0	0	0	0.2
5	9	41	15	0.2	31	0	15	1.2
6	19	44	61	0.7	91	0	61	3.7
7	30	46	156	1.7	177	0	156	8.1
8	40	48	293	3.2	262	0	293	13.9
9	43	50	429	4.7	308	0	429	19.1
10	37	51	473	5.1	279	895	222	20.1
11	19	52	302	3.3	149	791	89	12.4
12	1	53	18	0.2	7	56	3	0.7
13								
14								
15								
Totals	200	--	1,747	19.1	1,304	1,742	1,268	79.4

Age: 28 Site index: 50 (25-year basis) Density class

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	2	31	0	0	0	0	0
4	10	37	0	0	0	0	0
5	26	42	46	0.5	94	0	46
6	45	45	151	1.6	222	0	151
7	61	48	321	3.5	362	0	321
8	67	50	506	5.5	451	0	506
9	57	51	582	6.3	419	0	582
10	29	52	388	4.2	229	754	182
11	2	54	30	0.3	15	80	9
12							
13							
14							
15							
Totals	299	--	2,024	21.9	1,792	834	1,797

Age: 28 Site index: 50 (25-year basis) Density class: 400

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	7	31	0	0	0	0	0	0.3
4	25	38	0	0	0	0	0	2.2
5	51	43	94	1.0	188	0	94	6.9
6	76	46	262	2.8	384	0	262	14.9
7	91	49	489	5.3	550	0	489	24.2
8	85	51	655	7.1	582	0	655	29.6
9	54	52	566	6.2	407	0	566	24.0
10	11	54	145	1.6	86	289	68	5.9
11								
12								
13								
14								
15								
Totals	400	--	2,211	24.0	2,197	289	2,134	108.0

Age: 28 Site index: 50 (25-year basis) Density cla

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2	2	22	0	0	0	0	0
3	17	32	0	0	0	0	0
4	46	39	0	0	0	0	0
5	80	44	153	1.7	302	0	153
6	108	47	382	4.2	555	0	382
7	114	50	635	6.9	710	0	635
8	91	52	722	7.8	640	0	722
9	40	54	430	4.7	308	0	430
10	2	55	22	0.2	13	44	10
11							
12							
13							
14							
15							
Totals	500	--	2,344	25.5	2,528	44	2,332

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 30 Site index: 50 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	37	0	0	0	0	0	0.2
8	42	15	0.2	29	0	15	1.1
18	45	60	0.6	88	0	60	3.5
29	48	153	1.7	172	0	153	7.7
38	50	290	3.2	258	0	290	13.4
43	51	434	4.7	312	0	434	18.8
38	53	500	5.4	295	976	235	20.6
22	54	366	4.0	181	978	108	14.6
2	55	48	0.5	20	153	9	1.9
200	--	1,866	20.3	1,355	2,107	1,304	81.8

Age: 30 Site index: 50 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	2	32	0	0	0	0	0	0.1
4	10	38	0	0	0	0	0	0.8
5	24	43	45	0.5	91	0	45	3.3
6	43	46	147	1.6	215	0	147	8.4
7	58	49	318	3.5	356	0	318	15.6
8	66	51	512	5.6	455	0	512	23.0
9	59	52	616	6.7	442	0	616	26.0
10	34	54	464	5.0	277	930	219	18.7
11	4	55	69	0.7	34	187	20	2.7
12								
13								
14								
15								
Totals	300	--	2,171	23.6	1,870	1,117	1,877	98.6

: 30 Site index: 50 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
7	32	0	0	0	0	0	0.3
23	39	0	0	0	0	0	2.0
48	44	92	1.0	181	0	92	6.5
73	47	259	2.8	376	0	259	14.3
88	50	492	5.3	550	0	492	23.6
86	52	681	7.4	603	0	681	29.9
59	54	637	6.9	458	0	637	26.2
16	55	222	2.4	131	455	105	8.7
400	--	2,383	25.8	2,299	455	2,266	111.5

Age: 30 Site index: 50 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	2	22	0	0	0	0	0	0
3	15	33	0	0	0	0	0	0.8
4	43	40	0	0	0	0	0	3.7
5	76	45	151	1.6	294	0	151	10.4
6	104	48	381	4.1	548	0	381	20.4
7	113	51	649	7.1	72[illegible]	0	649	30.3
8	95	53	77[illegible]	8.4	684	0	77[illegible]	[illegible]
9	48	55	527	5.7	378	0	527	21.2
10	4	56	5[illegible]	0.6	[illegible]1	111	25	2.0
11								
12								
13								
14								
15								
Totals	500	--	2,534	27.5	2,658	111	2,506	121.[illegible]

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 10 Site index: 60 (25-year basis) Density class: 200

.b.h. class nches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	10	21	0	0	0	0	0	0.8
5	47	[illegible]	25	[illegible]	104	0	0	6.4
6	79	25	111	1.2	225	0	0	15.4
7	59	27	146	1.6	195	0	0	15.8
8	6	28	23	0.2	22	0	0	2.1
9								
10								
11								
12								
13								
14								
15								
otals	201	--	305	[illegible]	546	0	0	40.5

Age: 10 Site index: 60 (25-year basis) Density class:

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Ba ar
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq.
1								
2								
3	5	18	0	0	0	0	0	0
4	52	21	0	0	0	0	0	4
5	112	24	64	0.7	255	0	0	1
6	105	26	153	1.7	306	0	0	20
7	26	27	66	0.7	87	0	0	6
8								
9								
10								
11								
12								
13								
14								
15								
Totals	300	--	283	3.1	648	0	0	4

Age: 10 Site index: 60 (25-year basis) Density class: 400

.b.h. class nches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	28	18	0	0	0	0	0	1.4
4	112	22	0	0	0	0	0	9.8
5	157	24	95	1.0	363	0	0	21.4
6	94	26	143	1.6	280	0	0	18.5
7	8	28	22	0.2	29	0	0	2.2
8								
9								
10								
11								
12								
13								
14								
15								
tals	399	--	260	2.8	672	0	0	53.3

Age: 10 Site index: 60 (25-year basis) Density class:

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2	4	12	0	0	0	0	0
3	67	18	0	0	0	0	0
4	168	22	0	0	0	0	0
5	179	25	115	[illegible]	421	0	0
6	78	27	124	[illegible]	[illegible]	0	0
7	[illegible]	28	9	0.1	12	0	0
8							
9							
10							
11							
12							
13							
14							
15							
Totals	499	--	248	2.7	671	0	0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

e: 12 Site index: 60 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
4	25	0	0	0	0	0	0.4
23	28	19	0.2	59	0	0	3.1
49	30	93	1.0	166	0	0	9.6
64	32	203	2.2	253	0	0	17.0
50	33	233	2.5	219	0	0	17.3
11	34	69	0.8	51	0	0	4.7
201	--	617	6.7	748	0	0	52.1

Age: 12 Site index: 60 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	2	21	0	0	0	0	0	0.1
4	25	26	0	0	0	0	0	2.2
5	67	29	60	0.6	176	0	0	9.1
6	96	31	188	2.0	331	0	0	18.8
7	82	33	270	2.9	334	0	0	22.0
8	27	34	152	1.4	123	0	0	9.5
9								
10								
11								
12								
13								
14								
15								
Totals	299	--	650	6.9	964	0	0	61.7

ge: 12 Site index: 60 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
13	22	0	0	0	0	0	0.6
62	26	0	0	0	0	0	5.4
115	29	108	1.2	309	0	0	15.7
126	32	255	2.8	443	0	0	24.7
74	33	251	2.7	309	0	0	19.9
9	35	47	0.5	44	0	0	3.3
399	--	661	7.2	1,105	0	0	69.6

Age: 12 Site index: 60 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	2	15	0	0	0	0	0	0
3	35	22	0	0	0	0	0	1.7
4	106	27	0	0	0	0	0	9.2
5	156	30	153	1.7	426	0	0	21.3
6	138	32	291	3.2	498	0	0	27.2
7	60	34	208	2.[illegible]	254	0	0	15.9
8	3	36	16	0.2	15	0	0	1.1
9								
10								
11								
12								
13								
14								
15								
Totals	500	--	668	7.4	1,193	0	0	76.4

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 12 Site index: 60 (25-year basis) Density class: 600

lass nches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	7	15	0	0	0	0	0	0.2
3	65	22	0	0	0	0	0	3.2
4	150	27	0	0	0	0	0	13.1
5	187	31	192	2.1	521	0	0	25.6
6	141	33	307	3.3	519	0	0	27.7
7	46	35	172	1.9	210	0	0	12.9
8	1	36	7	0.1	7	0	0	0.5
9								
10								
11								
12								
13								
14								
15								
tals	599	--	678	7.4	1,257	0	0	83.2

Age: 12 Site index: 60 (25-year basis) Density class:

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Ba ar
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq.
1								
2	18	16	0	0	0	0	0	
3	100	23	0	0	0	0	0	4
4	190	28	0	0	0	0	0	1
5	210	31	225	2.4	595	0	0	2
6	140	34	316	3.4	528	0	0	2
7	41	36	152	1.7	183	0	0	1
8	1	37	5	0.1	4	0	0	
9								
10								
11								
12								
13								
14								
15								
Totals	700	--	698	7.6	1,310	0	0	8

Age: 12 Site index: 60 (25-year basis) Density class: 800

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	34	16	0	0	0	0	0	0.7
3	136	24	0	0	0	0	0	6.7
4	226	28	0	0	0	0	0	19.7
5	226	32	254	2.8	653	0	0	30.9
6	139	35	323	3.5	535	0	0	27.3
7	38	36	143	1.6	172	0	0	10.1
8	1	38	5	0.1	5	0	0	0.3
9								
10								
11								
12								
13								
14								
15								
Totals	800	--	725	8.0	1,365	0	0	95.7

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 14 Site index: 60 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Sawtimber	Pulpwood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
3	28	0	0	0	0	0	0.2
14	32	16	0.2	41	0	16	2.0
34	34	78	0.8	128	0	78	6.6
51	36	192	2.1	231	0	192	13.6
55	38	303	3.3	278	0	303	19.2
37	39	281	3.1	204	0	281	16.5
6	40	63	0.7	37	77	29	3.5
200	--	933	10.2	919	77	899	61.6

Age: 14 Site index: 60 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Sawtimber	Pulpwood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	24	0	0	0	0	0	0.1
4	16	29	0	0	0	0	0	1.4
5	45	33	53	0.6	133	0	0	6.2
6	75	35	179	1.9	293	0	0	14.7
7	85	37	330	3.6	394	0	0	22.7
8	62	39	350	3.8	321	0	0	21.6
9	16	40	121	1.3	88	0	0	6.9
10								
11								
12								
13								
14								
15								
Totals	300	--	1,033	11.2	1,229	0	0	73.6

e: 14 Site index: 60 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Sawtimber	Pulpwood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
8	24	0	0	0	0	0	0.4
41	30	0	0	0	0	0	3.6
85	33	103	1.1	254	0	0	11.6
113	36	278	3.0	451	0	0	22.2
101	38	403	4.4	478	0	0	27.0
49	40	282	3.1	258	0	0	17.0
3	41	25	0.3	18	0	0	1.4
400	--	1,091	11.9	1,459	0	0	83.2

Age: 14 Site index: 60 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Sawtimber	Pulpwood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	17	0	0	0	0	0	0
3	22	25	0	0	0	0	0	1.1
4	74	30	0	0	0	0	0	6.5
5	126	34	159	1.7	383	0	0	17.2
6	141	37	358	3.9	574	0	0	27.7
7	102	39	421	4.6	497	0	0	27.4
8	33	40	196	2.1	178	0	0	11.4
9								
10								
11								
12								
13								
14								
15								
Totals	499	--	1,134	12.3	1,632	0	0	91.3

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 14 Site index: 60 (25-year basis) Density class: 600

.b.h. ass ·hes)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	5	18	0	0	0	0	0	0.1
3	44	26	0	0	0	0	0	2.1
4	111	31	0	0	0	0	0	9.7
5	162	35	217	2.3	504	0	0	22.1
6	159	38	416	4.5	660	0	0	31.2
7	97	40	411	4.5	483	0	0	26.0
8	22	41	135	1.5	122	0	0	7.7
9								
10								
11								
12								
13								
14								
15								
tals	600	--	1,175	12.8	1,769	0	0	98.9

Age: 14 Site index: 60 (25-year basis) Density class: 7

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Bas are
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq.
1								
2	12	18	0	0	0	0	0	0.
3	70	26	0	0	0	0	0	3.
4	149	32	0	0	0	0	0	13.
5	193	36	264	2.9	609	0	0	26.
6	170	38	459	5.0	721	0	0	33.
7	90	41	397	4.3	460	0	0	24.
8	16	42	100	1.1	91	0	0	5.
9								
10								
11								
12								
13								
14								
15								
Totals	700	--	1,216	13.3	1,881	0	0	106.

Age: 14 Site index: 60 (25-year basis) Density class: 800

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	23	18	0	0	0	0	0	0.5
3	100	27	0	0	0	0	0	4.9
4	185	32	0	0	0	0	0	16.1
5	218	36	310	3.4	704	0	0	29.8
6	176	39	490	5.3	764	0	0	34.5
7	85	42	378	4.1	439	0	0	22.6
8	13	42	82	0.9	74	0	0	4.4
9								
10								
11								
12								
13								
14								
15								
Totals	800	--	1,260	13.7	1,981	0	0	112.8

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 16   Site index: 60 (25-year basis)   Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	31	0	0	0	0	0	0.2
10	35	14	0.1	32	0	14	1.4
25	38	67	0.7	107	0	67	5.0
41	40	176	1.9	207	0	176	11.0
50	42	313	3.4	284	0	313	17.6
46	43	384	4.2	278	0	384	20.2
24	44	259	2.8	152	392	120	12.9
1	45	18	0.2	9	40	5	0.8
199	--	1,231	13.3	1,069	432	1,079	69.1

Age: 16   Site index: 60 (25-year basis)   Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	26	0	0	0	0	0	0
4	11	32	0	0	0	0	0	1.0
5	34	36	47	0.5	108	0	47	4.6
6	60	39	165	1.8	258	0	165	11.9
7	77	41	338	3.7	394	0	338	20.6
8	72	43	456	5.0	412	0	456	25.0
9	40	44	347	3.8	251	0	347	17.8
10	4	45	48	0.5	28	75	22	2.3
11								
12								
13								
14								
15								
Totals	299	--	1,401	15.3	1,451	75	1,375	83.2

: 16   Site index: 60 (25-year basis)   Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
6	27	0	0	0	0	0	0.3
30	33	0	0	0	0	0	2.6
67	37	97	1.0	217	0	0	9.1
98	40	276	3.0	427	0	0	19.2
103	42	466	5.1	540	0	0	27.6
74	44	482	5.2	436	0	0	25.8
22	45	195	2.1	141	0	0	9.8
400	--	1,516	16.4	1,761	0	0	94.4

Age: 16   Site index: 60 (25-year basis)   Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	19	0	0	0	0	0	0
3	16	28	0	0	0	0	0	0.8
4	57	34	0	0	0	0	0	4.9
5	104	38	155	1.7	342	0	0	14.1
6	130	41	379	4.1	583	0	0	25.6
7	118	43	545	5.9	629	0	0	31.4
8	65	45	436	4.7	393	0	0	22.8
9	10	46	87	0.9	63	0	0	4.2
10								
11								
12								
13								
14								
15								
Totals	501	--	1,602	17.3	2,010	0	0	103.8

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 16 Site index: 60 (25-year basis) Density class: 600

.b.h. class nches	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	[illegible]	19	0	0	0	0	0	0.1
3	[illegible]	28	0	0	0	0	0	1.6
4	88	[illegible]	0	0	0	0	0	7.7
5	140	[illegible]	217	2.4	470	0	0	19.0
6	156	42	468	5.1	[illegible]	0	0	30.7
7	123	44	584	6.4	670	0	0	32.8
8	54	46	[illegible]	4.0	331	0	0	18.7
9	4	47	38	0.4	27	0	0	1.8
10								
11								
12								
13								
14								
15								
tals	600	--	1,676	[illegible]	2,211	0	0	112.4

Age: 16 Site index: 60 (25-year basis) Density class:

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Ba ar
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq.
1								
2	9	20	0	0	0	0	0	0
3	54	29	0	0	0	0	0	2
4	122	35	0	0	0	0	0	10
5	173	39	279	3.0	594	0	0	23
6	175	42	541	5.9	816	0	0	34
7	122	45	599	6.5	683	0	0	32
8	44	47	308	3.3	276	0	0	1
9	2	48	17	0.2	12	0	0	
10								
11								
12								
13								
14								
15								
Totals	701	--	1,744	18.9	2,381	0	0	12

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

ge: 18 Site index: 60 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	34	0	0	0	0	0	0.1
8	38	12	0.1	27	0	12	1.1
20	41	60	0.7	92	0	60	4.0
35	43	163	1.8	188	0	163	9.[illegible]
46	45	307	3.3	277	0	307	15.9
47	46	427	4.6	308	0	427	20.6
34	48	402	4.4	2[illegible]7	691	188	18.5
9	49	138	1.5	68	340	40	6.1
200	--	1,509	16.4	1,197	1,031	1,197	75.6

Age: 18 Site index: 60 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	28	0	0	0	0	0	0
4	9	35	0	0	0	0	0	0.8
5	27	39	43	0.5	40	0	43	[illegible].7
6	51	42	154	1.7	2[illegible]	0	154	9.9
7	69	44	[illegible]	[illegible].6	381	0	[illegible]	18.4
8	72	46	501	5.4	450	0	501	25.2
9	54	48	505	5.5	364	0	505	23.8
10	18	49	21[illegible]	2.[illegible]	126	[illegible]77	100	9.6
11								
12								
13								
14								
15								
Totals	301	--	1,748	19.0	1,594	[illegible]77	1,6[illegible]5	91.4

ge: 18 Site index: 60 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
5	29	0	0	0	0	0	0.2
24	35	0	0	0	0	0	2.1
55	40	90	1.0	192	0	90	7.5
85	43	267	2.9	401	0	267	16.8
99	45	490	5.3	558	0	490	26.4
85	47	604	6.6	541	0	604	29.6
43	49	417	4.5	301	0	417	19.2
4	50	48	0.5	29	88	23	2.1
400	--	1,916	20.8	2,022	88	1,891	103.9

Age: 18 Site index: 60 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	20	0	0	0	0	0	0
3	13	30	0	0	0	0	0	0.6
4	46	36	0	0	0	0	0	4.0
5	88	41	149	1.6	311	0	0	12.0
6	119	44	383	4.2	570	0	0	2[illegible]
7	120	46	612	6.7	694	0	0	[illegible]2.1
8	85	48	622	6.8	556	0	0	29.8
9	28	50	278	3.0	200	0	0	12.4
10								
11								
12								
13								
14								
15								
Totals	500	--	2,044	22.3	2,3[illegible]1	0	0	114.2

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 18 Site index: 60 (25-year basis) Density class: 600

.b.h. lass [illegible]	Irees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	3	21	0	0	[illegible]	0	0	0.1
3	26	[illegible]	0	0	0	0	0	1.3
4	7	37	0	0	0	0	0	6.4
5	122	42	215	2.3	440	0	0	16.7
6	148	[illegible]	[illegible]	5.3	726	0	0	29.1
7	[illegible]	47	690	7.6	786	0	0	35.6
8	[illegible]	49	590	6.4	526	0	0	27.5
9	16	51	167	1.8	120	0	0	7.3
10								
11								
12								
13								
14								
15								
tals	600	--	2,159	23.4	2,598	0	0	124.0

Age: 18 Site index: 60 (25-year basis) Density class: 7

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Bas are
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq.
1								
2	7	21	0	0	0	0	0	0.
3	44	31	0	0	0	0	0	2.
4	[illegible]	38	0	0	0	0	0	9.
5	155	42	283	[illegible]	570	0	0	21.
6	172	46	587	6.4	862	0	0	33.
7	[illegible]	48	748	8.1	842	0	0	37.
8	70	50	[illegible]	5.8	478	0	0	24.
9	10	52	102	1.1	7	0	0	4.
10								
11								
12								
13								
14								
15								
Totals	700	--	2,258	24.5	2,825	0	0	132.

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 20 Site index: 60 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	36	0	0	0	0	0	0.1
7	40	11	0.1	24	0	11	0.9
17	44	55	0.6	83	0	55	3.4
30	46	153	1.7	173	0	153	8.1
41	48	298	3.2	267	0	298	14.4
45	49	444	4.8	319	0	444	20.0
38	51	487	5.3	288	908	229	21.0
19	52	300	3.3	148	779	88	12.5
1	53	16	0.2	6	49	3	0.6
199	--	1,764	19.2	1,308	1,736	1,281	81.0

Age: 20 Site index: 60 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	30	0	0	0	0	0	0
4	7	37	0	0	0	0	0	0.6
5	23	41	40	0.4	82	0	40	3.1
6	44	44	144	1.6	214	0	144	8.6
7	62	47	323	3.5	366	0	323	16.6
8	70	49	520	5.7	464	0	520	24.4
9	60	51	602	6.5	434	0	602	26.5
10	31	52	402	4.4	237	770	189	16.9
11	2	53	37	0.4	18	99	11	1.5
12								
13								
14								
15								
Totals	300	--	2,068	22.5	1,815	869	1,829	98.2

: 20 Site index: 60 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
4	31	0	0	0	0	0	0.2
20	38	0	0	0	0	0	1.7
47	42	85	0.9	172	0	85	6.4
76	46	257	2.8	378	0	257	14.9
93	48	497	5.4	560	0	497	24.9
89	50	676	7.3	602	0	676	30.9
58	52	595	6.5	428	0	595	25.6
14	53	180	2.0	107	355	85	7.4
401	--	2,290	24.9	2,247	355	2,195	112.0

Age: 20 Site index: 60 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	22	0	0	0	0	0	0
3	10	32	0	0	0	0	0	0.5
4	39	38	0	0	0	0	0	3.4
5	77	43	144	1.6	286	0	144	10.5
6	109	46	379	4.1	567	0	379	21.3
7	118	49	648	7.0	726	0	648	31.6
8	96	51	752	8.2	667	0	752	33.6
9	46	53	489	5.3	351	0	489	20.5
10	4	54	53	0.6	31	106	25	2.1
11								
12								
13								
14								
15								
Totals	500	--	2,465	26.8	2,628	106	2,437	123.5

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 20 Site index: 60 (25-year basis) Density class: 600

.b.h. class Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	2	22	0	0	0	0	0	0
3	22	32	0	0	0	0	0	1.1
4	64	39	0	0	0	0	0	5.5
5	109	44	211	2.3	413	0	211	14.8
6	139	48	500	5.4	724	0	500	27.3
7	136	50	766	8.3	857	0	766	36.4
8	95	52	766	8.3	679	0	766	33.3
9	[illegible]	54	359	3.9	258	0	359	14.7
10	1	56	[illegible]	0.1	6	20	4	0.4
11								
12								
13								
14								
15								
otals	600	--	2,611	28.3	2,937	20	2,606	133.5

Age: 20 Site index: 60 (25-year basis) Density class:

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Ba ar
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq.
1								
2	6	23	0	0	0	0	0	0
3	37	33	0	0	0	0	0	1
4	90	40	0	0	0	0	0	7
5	141	45	283	3.1	546	0	0	19
6	166	49	613	6.7	881	0	0	32
7	148	51	853	9.3	947	0	0	39
8	90	54	741	8.1	655	0	0	31
9	23	55	252	2.7	181	0	0	10
10								
11								
12								
13								
14								
15								
Totals	701	--	2,742	29.9	3,210	0	0	14

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

e: 22 Site index: 60 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	38	0	0	0	0	0	0.1
6	42	11	0.1	21	0	11	0.8
15	46	52	0.6	76	0	52	3.0
27	48	144	1.6	162	0	144	7.2
38	50	289	3.1	257	0	289	13.2
44	52	450	4.9	324	0	450	19.2
40	53	538	5.8	318	1,065	253	21.9
26	54	427	4.6	211	1,151	126	16.8
4	55	88	1.0	37	282	16	3.4
201	--	1,999	21.7	1,406	2,498	1,341	85.6

Age: 22 Site index: 60 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	32	0	0	0	0	0	0
4	6	39	0	0	0	0	0	0.5
5	20	43	38	0.4	75	0	38	2.7
6	39	47	136	1.5	199	0	136	7.6
7	57	49	313	3.4	351	0	313	15.2
8	67	52	527	5.7	468	0	527	23.4
9	62	53	662	7.2	476	0	662	27.6
10	40	54	550	6.0	325	1,115	259	21.9
11	8	56	138	1.5	68	378	41	5.3
12								
13								
14								
15								
Totals	300	--	2,364	25.7	1,962	1,493	1,976	104.2

: 22 Site index: 60 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
3	33	0	0	0	0	0	0.2
17	40	0	0	0	0	0	1.5
42	44	81	0.9	158	0	81	5.7
69	48	248	2.7	358	0	248	13.5
88	50	496	5.4	554	0	496	23.5
89	53	719	7.8	636	0	719	31.1
67	54	726	7.9	521	0	726	29.5
25	56	357	3.9	211	741	168	13.9
400	--	2,627	28.6	2,438	741	2,438	118.9

Age: 22 Site index: 60 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	9	33	0	0	0	0	0	0.4
4	34	40	0	0	0	0	0	3.0
5	69	45	138	1.5	267	0	138	9.4
6	100	49	373	4.1	535	0	373	19.7
7	115	52	666	7.2	741	0	666	30.7
8	102	54	842	9.2	744	0	842	35.5
9	60	56	671	7.3	482	0	671	26.6
10	11	57	160	1.7	94	340	76	6.1
11								
12								
13								
14								
15								
Totals	500	--	2,850	31.0	2,863	340	2,766	131.4

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 22   Site index: 60 (25-year basis)   Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	2	25	0	0	0	0	0	0
3	19	34	0	0	0	0	[illegible]	0.9
4	55	41	0	0	0	0	0	4.8
5	99	46	206	2.2	390	0	206	13.4
6	131	50	501	5.4	714	0	501	25.7
7	136	53	811	8.8	897	0	811	36.4
8	106	55	900	9.8	794	0	900	37.0
9	49	57	557	6.1	400	0	557	21.6
10	4	58	57	0.6	34	124	27	2.1
11								
12								
13								
14								
15								
Totals	601	--	3,032	32.9	3,229	124	3,002	141.9

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

ge: 24 Site index: 60 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	39	0	0	0	0	0	0.1
5	44	10	0.1	19	0	10	0.7
14	48	49	0.5	71	0	49	2.7
24	50	138	1.5	154	0	138	6.5
35	52	281	3.1	250	0	281	12.2
42	54	450	4.9	324	0	450	18.4
41	56	570	6.2	337	1,178	269	22.2
30	57	519	5.6	257	1,440	154	19.5
9	58	196	2.1	82	640	57	7.2
201	--	2,213	24.0	1,494	3,258	1,388	89.5

Age: 24 Site index: 60 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	6	40	0	0	0	0	0	0.5
5	18	45	36	0.4	69	0	36	2.4
6	35	49	130	1.4	187	0	130	6.9
7	53	52	304	3.3	339	0	304	14.1
8	64	54	528	5.7	466	0	528	22.3
9	63	55	700	7.6	502	0	700	27.9
10	46	57	660	7.2	391	1,397	312	25.1
11	15	58	275	3.0	136	774	82	10.1
12								
13								
14								
15								
Totals	300	--	2,633	28.6	2,090	2,171	2,092	109.3

e: 24 Site index: 60 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
3	34	0	0	0	0	0	0.1
15	41	0	0	0	0	0	1.3
37	46	78	0.8	148	0	78	5.1
63	50	240	2.6	342	0	240	12.4
83	53	492	5.3	545	0	492	22.2
88	55	745	8.1	658	0	745	30.8
72	57	821	8.9	589	0	821	31.9
36	58	525	5.7	311	1,136	249	19.5
3	59	48	0.5	24	137	14	1.7
400	--	2,949	31.9	2,617	1,273	2,639	125.0

Age: 24 Site index: 60 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	8	35	0	0	0	0	0	0.4
4	30	42	0	0	0	0	0	2.6
5	62	47	134	1.5	251	0	134	8.5
6	93	51	366	4.0	519	0	366	18.3
7	111	54	675	7.3	744	0	675	29.6
8	104	56	905	9.8	797	0	905	36.4
9	70	58	819	8.9	587	0	819	31.1
10	20	59	307	3.3	182	677	145	11.1
11								
12								
13								
14								
15								
Totals	498	--	3,206	34.8	3,080	677	3,044	138.0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 24 Site index: 60 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	2	24	0	0	0	0	0	0
3	16	36	0	0	0	0	0	0.8
4	50	43	0	0	0	0	0	4.3
5	90	48	201	2.2	372	0	201	12.3
6	124	52	499	5.4	702	0	499	24.3
7	134	55	840	9.1	924	0	840	35.9
8	113	57	1,002	10.9	881	0	1,002	39.3
9	62	59	737	8.0	527	0	737	27.3
10	9	61	145	1.6	86	326	69	5.1
11								
12								
13								
14								
15								
Totals	600	--	3,424	37.2	3,492	326	3,348	149.3

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

ge: 26   Site index: 60 (25-year basis)   Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	41	0	0	0	0	0	0.1
5	46	10	0.1	18	0	10	0.6
12	49	47	0.5	67	0	47	2.4
23	52	132	1.4	147	0	132	6.0
33	54	274	3.0	242	0	274	11.4
40	56	448	4.9	322	0	448	17.6
41	58	590	6.4	349	1,263	279	22.1
32	59	586	6.4	291	1,663	174	21.3
14	60	313	3.4	132	1,040	59	11.0
201	--	2,400	26.1	1,568	3,966	1,423	92.5

Age: 26   Site index: 60 (25-year basis)   Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	34	0	0	0	0	0	0
4	5	42	0	0	0	0	0	0.4
5	16	47	34	0.4	64	0	34	2.2
6	32	50	125	1.4	178	0	125	6.3
7	49	53	296	3.2	328	0	296	13.1
8	61	56	525	5.7	463	0	525	21.4
9	63	57	725	7.9	520	0	725	27.8
10	50	59	743	8.1	439	1,625	352	27.2
11	22	60	416	4.5	206	1,196	124	14.7
12	1	61	15	0.2	7	51	3	0.5
13								
14								
15								
Totals	300	--	2,879	31.4	2,205	2,872	2,184	113.6

e: 26   Site index: 60 (25-year basis)   Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	35	0	0	0	0	0	0.1
14	43	0	0	0	0	0	1.2
34	48	75	0.8	139	0	75	4.7
58	52	233	2.5	328	0	233	11.5
79	54	487	5.3	536	0	487	21.0
87	57	761	8.3	670	0	761	30.2
76	59	892	9.7	639	0	892	33.4
44	60	669	7.3	397	1,492	317	23.9
7	61	125	1.4	62	365	37	4.3
401	--	3,242	35.3	2,771	1,857	2,802	130.3

Age: 26   Site index: 60 (25-year basis)   Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	7	36	0	0	0	0	0	0.3
4	27	44	0	0	0	0	0	2.4
5	57	49	130	1.4	239	0	130	7.8
6	88	53	359	3.9	504	0	359	17.2
7	107	56	679	7.4	746	0	679	28.6
8	105	58	949	10.3	834	0	949	36.7
9	78	60	938	10.2	672	0	938	34.2
10	30	62	466	5.1	276	1,060	221	16.3
11	1	63	12	0.1	6	34	3	0.4
12								
13								
14								
15								
Totals	500	--	3,533	38.4	3,277	1,094	3,279	143.9

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 26 Site index: 60 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	25		0	0	0	0	0
3	15	37	0	0	0	0	0	0.7
4	45	45	0	0	0	0	0	3.9
5	84	50	196	2.1	356	0	196	11.5
6	118	54	495	5.4	690	0	495	23.1
7	132	57	859	9.3	938	0	859	35.2
8	117	59	1,079	11.7	946	0	1,079	40.8
9	72	61	891	9.7	637	0	891	31.8
10	16	63	262	2.9	155	607	125	9.0
11								
12								
13								
14								
15								
Totals	600	--	3,782	41.1	3,722	607	3,645	156.0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

e: 28 Site index: 60 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	42	0	0	0	0	0	0.1
4	47	9	0.1	17	0	9	0.6
11	51	45	0.5	63	0	45	2.2
21	54	128	1.4	141	0	128	5.6
31	56	268	2.9	236	0	268	10.8
38	58	445	4.8	319	0	445	16.9
40	59	603	6.6	357	1,328	286	21.9
34	61	636	6.9	315	1,838	190	22.3
18	62	414	4.5	174	1,393	78	14.1
1	62	36	0.4	13	133	5	1.2
199	--	2,584	28.1	1,635	4,692	1,454	95.7

Age: 28 Site index: 60 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	5	43	0	0	0	0	0	0.4
5	15	48	33	0.4	61	0	33	2.0
6	30	52	121	1.3	170	0	121	5.9
7	46	55	289	3.1	419	0	289	12.4
8	59	57	522	5.7	459	0	522	20.5
9	62	59	742	8.1	531	0	742	27.5
10	52	61	805	8.8	477	1,808	382	28.6
11	28	62	538	5.8	268	1,576	161	18.5
12	2	63	57	0.6	24	194	11	1.9
13								
14								
15								
Totals	299	--	3,107	33.8	2,409	3,578	2,261	117.7

: 28 Site index: 60 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	36	0	0	0	0	0	0.1
13	44	0	0	0	0	0	1.1
32	49	72	0.8	133	0	72	4.3
55	53	227	2.5	317	0	227	10.8
75	56	481	5.2	526	0	481	20.1
85	58	771	8.4	676	0	771	29.6
77	60	944	10.3	676	0	944	34.2
50	62	788	8.6	467	1,803	374	27.3
12	63	226	2.5	113	670	68	7.6
401	--	3,509	38.3	2,908	2,473	2,937	135.1

Age: 28 Site index: 60 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	7	37	0	0	0	0	0	0.3
4	25	45	0	0	0	0	0	2.2
5	53	50	126	1.4	228	0	126	7.
6	83	54	353	3.8	490	0	353	16.3
7	103	58	680	7.4	743	0	680	27.6
8	105	60	981	10.7	860	0	981	36.7
9	83	62	1,033	11.2	739	0	1,033	36.5
10	38	63	616	6.7	366	1,436	293	20.9
11	2	65	45	0.5	23	136	14	1.5
12								
13								
14								
15								
Totals	499	--	3,834	41.7	3,449	1,572	3,480	149.3

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 30 Site index: 60 (25-year basis) Density class: 200

b.h. lass ches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	1	43	0	0	0	0	0	0.1
5	4	48	9	0.1	16	0	9	0.5
6	11	52	43	0.5	61	0	43	2.1
7	20	55	124	1.3	137	0	124	5.3
8	29	58	262	2.8	230	0	262	10.3
9	37	59	442	4.8	316	0	442	16.3
10	40	61	611	6.6	362	1,378	290	21.6
11	35	62	673	7.3	325	1,977	201	23.0
12	21	63	497	5.4	209	1,692	94	16.5
13	3	64	84	0.9	41	313	11	2.7
14								
15								
tals	201	--	2,745	29.7	1,697	5,360	1,476	98.4

Age: 30 Site index: 60 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	4	44	0	0	0	0	0	0.4
5	14	50	32	0.3	58	0	32	1.9
6	28	53	117	1.3	164	0	117	5.5
7	44	56	283	3.1	310	0	283	11.8
8	57	59	518	5.6	455	0	518	19.8
9	61	61	753	8.2	539	0	753	27.1
10	54	62	853	9.3	505	1,958	405	29.4
11	32	64	640	7.0	319	1,904	192	21.4
12	5	65	119	1.3	50	409	23	3.9
13								
14								
15								
Totals	299	--	3,315	36.1	2,400	4,271	2,323	121.2

Age: 30 Site index: 60 (25-year basis) Density class: 400

b.h. lass ches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	2	37	0	0	0	0	0	0.1
4	12	45	0	0	0	0	0	1.0
5	30	51	70	0.8	127	0	70	4.0
6	52	55	221	2.4	307	0	221	10.2
7	72	58	475	5.2	518	0	475	19.2
8	83	60	776	8.4	680	0	776	29.0
9	78	62	984	10.7	703	0	984	34.6
10	55	64	886	9.6	525	2,071	422	29.9
11	17	65	340	3.7	169	1,024	102	11.1
12								
13								
14								
15								
tals	401	--	3,752	40.8	3,029	3,095	3,050	139.1

Age: 30 Site index: 60 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	6	38	0	0	0	0	0	0.3
4	23	46	0	0	0	0	0	2.0
5	50	52	123	1.3	219	0	123	6.8
6	79	56	347	3.8	478	0	347	15.5
7	100	59	678	7.4	738	0	678	26.8
8	105	61	1,005	10.9	878	0	1,005	36.
9	86	63	1,109	12.1	792	0	1,109	38.1
10	45	65	751	8.2	446	1,786	358	24.
11	5	66	99	1.1	50	302	30	3.
12								
13								
14								
15								
Totals	499	--	4,112	44.8	3,601	2,088	3,650	153.

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

10 Site index: 70 (25-year basis) Density class: 200

ees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
mber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
3	24	0	0	0	0	0	0.2
25	27	20	0.2	64	0	0	3.5
61	29	110	1.2	201	0	0	12.1
74	31	223	2.4	282	0	0	19.7
36	32	164	1.8	155	0	0	12.8
1	33	4	0	3	0	0	0.3
200	--	521	5.6	705	0	0	48.6

Age: 10 Site index: 70 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	20	0	0	0	0	0	0
4	24	25	0	0	0	0	0	2.1
5	80	28	66	0.7	205	0	0	11.0
6	113	30	209	2.3	376	0	0	22.1
7	74	31	231	2.5	290	0	0	19.8
8	8	33	37	0.4	35	0	0	2.8
9								
10								
11								
12								
13								
14								
15								
Totals	300	--	543	5.9	906	0	0	57.8

10 Site index: 70 (25-year basis) Density class: 400

ees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
mber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
8	21	0	0	0	0	0	0.4
66	25	0	0	0	0	0	5.8
136	28	117	1.3	354	0	0	18.6
135	30	259	2.8	460	0	0	26.5
53	32	171	1.9	213	0	0	14.2
1	34	5	0.1	4	0	0	0.4
399	--	552	6.1	1,031	0	0	65.9

Age: 10 Site index: 70 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	28	21	0	0	0	0	0	1.3
4	116	26	0	0	0	0	0	10.2
5	179	29	161	1.8	472	0	0	24.4
6	139	31	276	3.0	483	0	0	27.3
7	38	33	126	1.4	156	0	0	10.2
8								
9								
10								
11								
12								
13								
14								
15								
Totals	500	--	563	6.2	1,111	0	0	73.4

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 10 Site index: 70 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	2	15	0	0	0	0	0	0
3	57	22	0	0	0	0	0	2.8
4	165	26	0	0	0	0	0	14.4
5	208	30	197	2.1	560	0	0	26.3
6	127	32	281	3.1	486	0	0	26.9
7	41	34	105	1.1	129	0	0	8.3
8								
9								
10								
11								
12								
13								
14								
15								
Totals	600	--	583	6.3	1,175	0	0	80.7

Age: 10 Site index: 70 (25-year basis) Density class: 7

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. f
1								
2	8	15	0	0	0	0	0	0.
3	93	22	0	0	0	0	0	4.
4	208	27	0	0	0	0	0	18.
5	228	30	226	2.5	624	0	0	31.
6	135	32	287	3.1	489	0	0	26.
7	29	34	101	1.1	123	0	0	7.
8								
9								
10								
11								
12								
13								
14								
15								
Totals	701	—	614	6.7	1,236	0	0	88.

Age: 10 Site index: 70 (25-year basis) Density class: 800

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	19	16	0	0	0	0	0	0.4
3	130	23	0	0	0	0	0	6.4
4	244	28	0	0	0	0	0	21.3
5	242	31	252	2.7	677	0	0	33.1
6	135	33	297	3.2	501	0	0	26.5
7	29	35	106	1.1	128	0	0	7.8
8								
9								
10								
11								
12								
13								
14								
15								
Totals	799	--	655	7.0	1,306	0	0	95.5

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

12   Site index: 70 (25-year basis)   Density class: 200

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	29	0	0	0	0	0	0.1
12	32	13	0.1	34	0	13	1.6
34	35	79	0.9	130	0	79	6.6
54	37	209	2.3	250	0	209	14.5
59	38	329	3.6	302	0	329	20.5
36	40	279	3.0	203	0	279	16.1
4	41	39	0.4	23	50	18	2.1
200	--	948	10.3	942	50	927	61.5

Age: 12   Site index: 70 (25-year basis)   Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	11	30	0	0	0	0	0	1.0
5	43	33	51	0.6	128	0	0	5.9
6	78	36	191	2.1	311	0	0	15.4
7	91	38	359	3.9	427	0	0	24.3
8	63	39	365	4.0	333	0	0	22.1
9	13	41	101	1.1	73	0	0	5.7
10								
11								
12								
13								
14								
15								
Totals	299	--	1,067	11.7	1,272	0	0	74.4

12   Site index: 70 (25-year basis)   Density class: 400

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
4	25	0	0	0	0	0	0.2
34	30	0	0	0	0	0	3.0
85	34	105	1.1	256	0	0	11.6
120	36	300	3.3	482	0	0	23.5
107	38	435	4.7	513	0	0	28.6
48	40	286	3.1	262	0	0	16.9
3	42	21	0.2	15	0	0	1.1
401	--	1,147	12.4	1,528	0	0	84.9

Age: 12   Site index: 70 (25-year basis)   Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	14	25	0	0	0	0	0	0.7
4	66	31	0	0	0	0	0	5.8
5	128	35	165	1.8	394	0	0	17.4
6	149	37	387	4.2	616	0	0	29.3
7	109	39	454	4.9	534	0	0	29.0
8	34	41	205	2.2	187	0	0	11.8
9								
10								
11								
12								
13								
14								
15								
Totals	500	--	1,211	13.1	1,731	0	0	94.0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 12 Site index: 70 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	18	0	0	0	0	0	0
3	31	26	0	0	0	0	0	1.5
4	104	32	0	0	0	0	0	9.0
5	166	35	224	2.4	521	0	0	22.7
6	169	38	451	4.9	712	0	0	33.2
7	104	40	449	4.9	525	0	0	27.9
8	25	42	154	1.7	140	0	0	8.6
9								
10								
11								
12								
13								
14								
15								
Totals	600	--	1,278	13.9	1,898	0	0	102.9

Age: 12 Site index: 70 (25-year basis) Density class:

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Ba ar
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq.
1								
2	4	18	0	0	0	0	0	0.
3	54	27	0	0	0	0	0	2
4	142	32	0	0	0	0	0	12
5	199	36	279	3.0	636	0	0	27.
6	181	39	500	5.4	780	0	0	35
7	100	41	441	4.8	513	0	0	26
8	20	43	129	1.4	116	0	0	7
9								
10								
11								
12								
13								
14								
15								
Totals	700	--	1,349	14.6	2,045	0	0	111

Age: 12 Site index: 70 (25-year basis) Density class: 800

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	11	18	0	0	0	0	0	0.2
3	81	27	0	0	0	0	0	4.0
4	178	33	0	0	0	0	0	15.6
5	226	37	329	3.6	738	0	0	30.9
6	190	40	539	5.9	833	0	0	37.2
7	96	42	437	4.8	505	0	0	25.7
8	18	44	119	1.3	108	0	0	6.3
9								
10								
11								
12								
13								
14								
15								
Totals	800	--	1,424	15.6	2,184	0	0	119.9

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 14 Site index: 70 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	33	0	0	0	0	0	0.1
7	37	10	0.1	23	0	10	1.0
22	40	62	0.7	96	0	62	4.3
40	42	179	1.9	208	0	179	10.6
51	44	336	3.6	303	0	336	17.9
49	45	433	4.7	313	0	433	21.6
28	46	319	3.5	188	523	149	15.1
2	47	36	0.4	18	86	10	1.6
200	--	1,375	14.9	1,149	609	1,179	72.2

Age: 14 Site index: 70 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	7	34	0	0	0	0	0	0.6
5	28	38	42	0.5	93	0	42	3.8
6	56	41	165	1.8	253	0	165	11.1
7	78	43	360	3.9	415	0	360	20.7
8	76	45	512	5.6	461	0	512	26.7
9	47	46	429	4.7	309	0	429	20.9
10	8	47	89	1.0	52	151	41	4.1
11								
12								
13								
14								
15								
Totals	300	--	1,597	17.5	1,583	151	1,549	87.9

: 14 Site index: 70 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	28	0	0	0	0	0	0.1
22	34	0	0	0	0	0	1.9
59	38	92	1.0	199	0	92	8.0
95	42	285	3.1	434	0	285	18.6
107	44	512	5.6	588	0	512	28.7
83	46	571	6.2	512	0	571	29.0
31	47	291	3.2	209	0	291	13.8
1	48	8	0.1	5	14	4	0.4
400	--	1,759	19.2	1,947	14	1,755	100.5

Age: 14 Site index: 70 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	9	29	0	0	0	0	0	0.4
4	44	35	0	0	0	0	0	3.9
5	95	39	154	1.7	327	0	0	13.0
6	130	42	403	4.4	607	0	0	25.5
7	126	45	617	6.7	704	0	0	33.6
8	78	47	552	6.0	495	0	0	27.3
9	18	48	170	1.8	122	0	0	7.9
10								
11								
12								
13								
14								
15								
Totals	500	--	1,896	20.6	2,255	0	0	111.6

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 14 Site index: 70 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	20	0	0	0	0	0	0
3	20	30	0	0	0	0	0	1.0
4	73	36	0	0	0	0	0	6.4
5	132	40	221	2.4	461	0	0	17.9
6	159	44	508	5.5	759	0	0	31.2
7	135	46	682	7.4	775	0	0	36.1
8	70	48	506	5.5	452	0	0	24.4
9	10	49	102	1.1	74	0	0	4.6
10								
11								
12								
13								
14								
15								
Totals	600	--	2,019	21.9	2,521	0	0	121.6

Age: 14 Site index: 70 (25-year basis) Density class:

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Ba ar
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq.
1								
2	3	21	0	0	0	0	0	0
3	36	30	0	0	0	0	0	1
4	105	37	0	0	0	0	0	9
5	166	41	289	3.1	594	0	0	22
6	182	44	598	6.5	887	0	0	35
7	139	47	721	7.8	817	0	0	37
8	62	49	461	5.0	411	0	0	21
9	7	50	69	0.8	50	0	0	
10								
11								
12								
13								
14								
15								
Totals	700	--	2,138	23.2	2,759	0	0	13

Age: 14 Site index: 70 (25-year basis) Density class: 800

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	7	21	0	0	0	0	0	0.2
3	57	31	0	0	0	0	0	2.8
4	137	38	0	0	0	0	0	12.0
5	198	42	356	3.9	720	0	0	26.9
6	200	46	675	7.3	993	0	0	39.2
7	140	48	747	8.1	841	0	0	37.5
8	56	50	428	4.7	381	0	0	19.6
9	5	52	54	0.6	39	0	0	2.3
10								
11								
12								
13								
14								
15								
Totals	800	--	2,260	24.6	2,974	0	0	140.5

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

e: 16 Site index: 70 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
5	41	9	0.1	18	0	9	0.7
16	44	52	0.6	78	0	52	3.2
31	46	157	1.7	178	0	157	8.2
44	48	318	3.5	284	0	318	15.2
48	50	473	5.1	340	0	473	21.2
39	51	500	5.4	296	942	235	21.4
17	52	264	2.9	130	690	78	10.9
200	--	1,773	19.3	1,324	1,632	1,322	80.8

Age: 16 Site index: 70 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	5	37	0	0	0	0	0	0.4
5	20	42	36	0.4	74	0	36	2.8
6	44	45	145	1.6	214	0	145	8.6
7	65	47	340	3.7	384	0	340	17.4
8	74	49	553	6.0	492	0	553	25.7
9	62	51	624	6.8	448	0	624	27.2
10	29	52	380	4.1	224	735	179	15.8
11	2	53	24	0.3	12	65	7	1.0
12								
13								
14								
15								
Totals	301	--	2,102	22.9	1,848	800	1,884	98.9

: 16 Site index: 70 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	31	0	0	0	0	0	0.1
16	38	0	0	0	0	0	1.4
45	42	82	0.9	165	0	82	6.1
77	46	265	2.9	388	0	265	15.2
98	48	524	5.7	590	0	524	26.1
92	50	710	7.7	631	0	710	32.2
58	52	603	6.5	433	0	603	25.7
12	53	168	1.8	99	334	79	6.8
400	--	2,352	25.5	2,306	334	2,263	113.6

Age: 16 Site index: 70 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	6	32	0	0	0	0	0	0.3
4	33	39	0	0	0	0	0	2.9
5	75	43	142	1.5	280	0	142	10.2
6	112	47	393	4.3	573	0	393	21.9
7	124	50	681	7.4	763	0	681	33.0
8	99	52	784	8.5	696	0	784	34.7
9	47	53	499	5.4	359	0	499	20.8
10	4	55	58	0.6	34	118	27	2.3
11								
12								
13								
14								
15								
Totals	500	--	2,557	27.7	2,705	118	2,526	126.1

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 16 Site index: 70 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	1	22	0	0	0	0	0	0
3	15	35	0	0	0	0	0	0.7
4	56	40	0	0	0	0	0	4.9
5	108	44	211	2.3	411	0	211	14.7
6	143	48	519	5.6	749	0	519	28.1
7	142	51	804	8.7	897	0	804	37.9
8	99	53	802	8.7	709	0	802	34.6
9	36	54	389	4.2	279	0	389	15.8
10	1	56	18	0.2	11	8	9	0.7
11								
12								
13								
14								
15								
Totals	601	--	2,743	29.7	3,056	8	2,734	137.4

Age: 16 Site index: 70 (25-year basis) Density class:

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		B
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq.
1								
2	2	27	0	0	0	0	0	
3	27	35	0	0	0	0	0	
4	82	40	0	0	0	0	0	
5	141	45	285	3.1	548	0	0	1
6	171	49	637	6.9	912	0	0	3
7	154	52	896	9.7	997	0	0	4
8	95	54	790	8.6	697	0	0	3
9	27	56	304	3.3	219	0	0	1
10								
11								
12								
13								
14								
15								
Totals	699	--	2,912	31.6	3,373	0	0	14

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 18 Site index: 70 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
4	44	8	0.1	15	0	8	0.5
13	47	46	0.5	67	0	46	2.5
25	50	142	1.5	159	0	142	6.8
38	52	299	3.2	265	0	299	13.1
45	54	478	5.2	344	0	478	19.7
42	55	585	6.4	346	1,201	276	23.0
28	56	480	5.2	237	1,323	142	18.2
5	57	116	1.3	48	377	22	4.3
200	--	2,154	23.4	1,481	2,901	1,413	88.1

Age: 18 Site index: 70 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	4	40	0	0	0	0	0	0.3
5	16	45	32	0.4	62	0	32	2.2
6	36	48	131	1.4	189	0	131	7.0
7	56	51	320	[illegible]	356	0	320	14.9
8	68	53	557	6.1	493	0	557	[illegible]
9	65	55	720	7.8	517	0	720	28.9
10	44	56	624	6.8	[illegible]	1,310	295	[illegible]
11	11	58	193	2.1	95	540	57	7.1
12								
13								
14								
15								
Totals	300	--	2,577	28.1	2,081	1,850	2,112	108.1

: 18 Site index: 70 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	34	0	0	0	0	0	0.1
12	41	0	0	0	0	0	1.1
36	46	74	0.8	142	0	74	4.9
65	50	247	2.7	353	0	247	12.8
88	52	516	5.6	572	0	516	23.5
92	54	773	8.4	682	0	773	32.2
72	56	812	8.8	582	0	812	31.8
31	58	457	5.0	270	980	216	17.1
2	59	27	0.3	14	76	[illegible]	1.0
399	--	2,906	31.6	2,615	1,056	2,646	124.5

Age: 18 Site index: 70 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	5	34	0	0	0	0	0	0.2
4	26	42	0	0	0	0	0	[illegible]
5	62	47	132	1.4	248	0	132	8.5
6	97	51	378	4.1	537	0	378	19.1
7	116	[illegible]	[illegible]	7.6	776	0	[illegible]	[illegible]
8	107	56	921	10.0	812	0	921	37.4
9	68	58	788	8.6	565	0	788	30.1
10	18	59	264	2.9	156	577	125	9.6
11								
12								
13								
14								
15								
Totals	499	--	3,186	34.6	3,094	577	3,047	138.3

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 18 Site index: 70 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	12	[illegible]	0	0	0	0	0	0.6
4	45	[illegible]	0	0	0	0	0	4.0
5	91	48	200	2.2	372	0	200	12.4
6	129	52	514	5.6	725	0	514	25.3
7	140	55	865	9.4	952	0	865	37.3
8	114	57	1,006	10.9	885	0	1,006	39.9
9	60	59	707	7.7	507	0	707	26.4
10	9	60	[illegible]	1.5	82	311	66	5.0
11								
12								
13								
14								
15								
Totals	600	--	[illegible]	37.3	3,523	311	3,358	150.9

Age: 18 Site index: 70 (25-year basis) Density class:7

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Ba ar
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq.
1								
2	2	25	0	0	0	0	0	
3	22	36	0	0	0	0	0	1
4	68	44	0	0	0	0	0	5
5	122	49	277	3.0	508	0	277	16
6	158	53	649	7.1	909	0	649	31
7	157	56	1,001	10.9	1,099	0	1,001	42
8	116	58	1,046	11.4	919	0	1,046	40
9	51	60	614	6.7	440	0	614	22
10	5	62	74	0.8	44	170	35	
11								
12								
13								
14								
15								
Totals	701	--	3,661	39.9	3,919	170	3,622	16

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 20 Site index: 70 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
3	47	7	0.1	13	0	7	0.5
11	50	42	0.5	60	0	42	2.1
22	53	130	1.4	144	0	130	5.8
33	55	282	3.1	249	0	282	11.5
41	57	472	5.1	339	0	472	18.2
42	59	625	6.8	370	1,362	296	23.0
33	60	615	6.7	305	1,766	183	21.9
14	61	315	3.4	133	1,055	59	10.9
199	--	2,488	27.1	1,613	4,183	1,471	93.9

Age: 20 Site index: 70 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	3	42	0	0	0	0	0	0.3
5	14	48	29	0.3	55	0	29	1.8
6	30	51	121	1.3	171	0	121	6.0
7	49	54	302	3.3	333	0	302	14.1
8	63	57	550	6.0	485	0	550	21.9
9	65	58	767	8.3	550	0	767	28.8
10	52	60	784	8.5	465	1,742	372	28.2
11	23	61	438	4.8	218	1,275	131	15.2
12	1	62	20	0.2	9	68	4	0.7
13								
14								
15								
Totals	300	--	3,011	32.7	2,286	3,085	2,276	116.0

: 20 Site index: 70 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	36	0	0	0	0	0	0
10	43	0	0	0	0	0	0.9
31	49	69	0.7	127	0	69	4.2
57	53	232	2.5	325	0	232	11.2
80	56	503	5.5	552	0	503	21.3
89	58	800	8.7	702	0	800	31.1
78	60	943	10.3	675	0	943	34.6
46	61	717	7.8	426	1,624	340	25.2
8	62	157	1.7	78	463	47	5.3
400	--	3,421	37.2	2,885	2,087	2,934	133.8

Age: 20 Site index: 70 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	4	37	0	0	0	0	0	0.2
4	22	44	0	0	0	0	0	1.9
5	53	50	124	1.3	225	0	124	7.3
6	87	54	363	3.9	505	0	363	17.0
7	109	57	705	7.7	773	0	705	29.1
8	109	59	1,000	10.9	876	0	1,000	37.9
9	81	61	1,001	10.9	717	0	1,001	35.9
10	34	63	540	5.9	320	1,246	257	18.5
11	2	64	32	0.4	16	96	10	1.1
12								
13								
14								
15								
Totals	501	--	3,765	41.0	3,432	1,342	3,460	148.9

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 20 Site index: 70 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	10	38	0	0	0	0	0	0.5
4	28	45	0	0	0	0	0	[illegible]
5	80	51	191	2.1	342	0	191	10.8
6	117	55	504	5.5	699	0	504	23.0
7	144	58	894	9.7	975	0	894	35.9
8	121	60	1,142	12.4	1,000	0	1,142	42.3
9	77	62	977	10.6	698	0	977	34.2
10	22	64	362	3.9	215	850	172	12.1
11								
12								
13								
14								
15								
Totals	599	--	4,070	44.2	3,929	850	3,880	162.1

Age: 20 Site index: 70 (25-year basis) Density class:

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Ba ar
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq.
1								
2	1	26	0	0	0	0	0	
3	18	38	0	0	0	0	0	0
4	58	46	0	0	0	0	0	5
5	108	52	267	2.9	475	0	267	14
6	146	56	648	7.0	897	0	648	28
7	156	59	1,067	11.6	1,155	0	1,067	41
8	128	62	1,235	13.4	1,079	0	1,235	44
9	70	64	911	9.9	651	0	911	31
10	14	66	235	2.5	139	556	111	7
11								
12								
13								
14								
15								
Totals	699	--	4,357	47.3	4,392	556	4,235	17

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

22 Site index: 70 (25-year basis) Density class: 200

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
3	49	6	0.1	12	0	6	0.4
10	53	39	0.4	55	0	39	1.9
19	56	122	1.3	134	0	122	5.1
30	58	269	2.9	236	0	269	10.4
38	60	463	5.0	322	0	463	16.9
41	62	644	7.0	383	1,466	306	22.5
36	63	701	7.6	349	2,071	210	23.7
21	64	493	5.4	209	1,688	94	16.2
2	65	70	0.8	26	262	9	2.3
200	--	2,807	30.5	1,736	5,487	1,518	99.4

Age: 22 Site index: 70 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	3	45	0	0	0	0	0	0.2
5	12	50	27	0.3	50	0	27	1.6
6	27	54	113	1.2	157	0	113	5.3
7	44	57	288	3.1	315	0	288	11.8
8	58	59	539	5.9	472	0	539	20.3
9	64	61	790	8.6	566	0	790	28.1
10	56	63	888	9.6	527	2,057	422	30.3
11	32	64	650	7.1	324	1,945	195	21.4
12	5	65	118	1.3	50	408	22	3.8
13								
14								
15								
Totals	301	--	3,413	37.1	2,461	4,410	2,396	122.8

22 Site index: 70 (25-year basis) Density class: 400

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
mber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	38	0	0	0	0	0	0
9	46	0	0	0	0	0	0.8
27	51	64	0.7	116	0	64	3.6
51	55	219	2.4	303	0	219	9.9
73	58	488	5.3	532	0	488	19.5
85	61	810	8.8	709	0	810	29.8
81	63	1,027	11.2	735	0	1,027	35.7
56	64	917	10.0	544	2,162	437	30.6
18	66	366	4.0	183	1,108	110	11.8
401	--	3,891	42.4	3,122	3,270	3,155	141.7

Age: 22 Site index: 70 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	3	38	0	0	0	0	0	0.2
4	19	47	0	0	0	0	0	1.7
5	47	52	117	1.3	207	0	117	6.4
6	78	56	349	3.8	479	0	349	15.4
7	102	60	700	7.6	761	0	700	27.3
8	108	62	1,046	11.4	914	0	1,046	37.6
9	89	64	1,155	12.6	826	0	1,155	39.2
10	48	66	798	8.7	473	1,913	380	26.0
11	7	67	138	1.5	69	423	42	4.3
12								
13								
14								
15								
Totals	501	--	4,303	46.9	3,729	2,336	3,789	158.1

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 22 Site index: 70 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	8	39	0	0	0	0	0	0.4
4	34	48	0	0	0	0	0	2.9
5	71	54	182	2.0	319	0	182	9.7
6	107	58	492	5.3	673	0	492	21.1
7	129	61	907	9.9	982	0	907	34.4
8	124	64	1,233	13.4	1,076	0	1,233	43.2
9	89	66	1,192	13.0	850	0	1,192	39.5
10	36	67	622	6.8	369	1,515	297	19.8
11	2	69	38	0.4	19	117	11	1.2
12								
13								
14								
15								
Totals	600	--	4,666	50.8	4,288	1,632	4,314	172.2

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 24 Site index: 70 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
3	51	6	0.1	11	0	6	0.3
8	55	36	0.4	50	0	36	1.7
17	58	115	1.3	126	0	115	4.6
27	61	258	2.8	226	0	258	9.5
36	63	454	4.9	325	0	454	15.8
40	64	652	7.1	387	1,534	310	21.8
37	66	756	8.2	376	2,285	227	24.4
25	67	626	6.8	265	2,181	120	19.7
6	68	189	2.1	69	713	24	5.8
199	--	3,092	33.7	1,835	6,713	1,550	103.6

Age: 24 Site index: 70 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	2	46	0	0	0	0	0	0.2
5	10	52	26	0.3	46	0	26	1.4
6	24	56	107	1.2	147	0	107	4.7
7	40	60	276	3.0	300	0	276	10.8
8	55	62	528	5.7	461	0	528	19.0
9	62	64	800	8.7	572	0	800	27.2
10	57	66	957	10.4	568	2,288	456	31.2
11	39	67	813	8.8	406	2,487	245	25.7
12	11	68	273	3.0	116	959	52	8.4
13								
14								
15								
Totals	300	--	3,780	41.1	2,616	5,734	2,490	128.6

24 Site index: 70 (25-year basis) Density class: 400

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	39	0	0	0	0	0	0
8	48	0	0	0	0	0	0.7
24	53	61	0.7	107	0	61	3.2
46	58	209	2.3	287	0	209	9.0
68	61	475	5.2	514	0	475	18.1
82	63	811	8.8	708	0	811	28.5
81	65	1,081	11.7	772	0	1,081	35.9
62	67	1,068	11.6	634	2,595	509	34.0
28	68	589	6.4	295	1,823	178	18.2
1	70	31	0.3	13	111	6	0.9
401	--	4,325	47.0	3,330	4,529	3,330	148.5

Age: 24 Site index: 70 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	3	40	0	0	0	0	0	0.1
4	17	49	0	0	0	0	0	1.5
5	42	54	111	1.2	193	0	111	5.7
6	72	59	336	3.7	458	0	336	14.1
7	96	62	692	7.5	747	0	692	25.7
8	106	65	1,073	11.7	935	0	1,073	36.8
9	93	67	1,266	13.8	904	0	1,266	41.1
10	58	69	1,016	11.0	603	2,507	485	31.6
11	14	70	303	3.3	152	949	92	9.1
12								
13								
14								
15								
Totals	501	—	4,797	52.2	3,992	3,456	4,055	165.7

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 24 Site index: 70 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	7	41	0	0	0	0	0	0.4
4	30	50	0	0	0	0	0	2.6
5	64	56	175	1.9	301	0	175	8.8
6	100	60	480	5.2	649	0	480	19.6
7	123	64	910	9.9	979	0	910	32.9
8	124	66	1,295	14.1	1,125	0	1,295	43.3
9	97	68	1,358	14.8	969	0	1,358	43.0
10	49	70	870	9.5	517	2,180	416	26.5
11	6	72	125	1.4	63	394	38	3.7
12								
13								
14								
15								
Totals	600	--	5,213	56.8	4,603	2,574	4,672	180.8

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

26 Site index: 70 (25-year basis) Density class: 200

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	53	6	0.1	10	0	6	0.3
[illegible]	57	35	0.4	48	0	35	1.5
16	60	110	1.2	120	0	110	4.2
25	63	249	2.7	217	0	249	8.8
34	65	444	4.8	318	0	444	14.9
39	66	655	7.1	389	1,581	312	21.1
37	68	793	8.6	396	2,440	239	24.7
28	69	726	7.9	309	2,561	139	22.0
11	70	333	3.6	121	1,269	45	9.9
200	--	3,351	36.4	1,928	7,851	1,577	107.4

Age: 26 Site index: 70 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	2	48	0	0	0	0	0	0.2
5	10	54	24	0.3	43	0	24	1.[illegible]
6	22	58	102	1.1	139	0	102	4.[illegible]
7	37	62	265	2.9	287	0	265	10.0
8	51	64	517	5.6	450	0	517	17.9
9	60	66	803	8.7	573	0	803	26.3
10	58	68	1,004	10.9	597	2,461	479	31.6
11	43	69	938	10.2	469	2,918	283	28.5
12	17	71	452	4.9	193	1,608	87	13.4
13								
14								
15								
Totals	300	--	4,105	44.6	2,751	6,987	2,560	133.5

: 26 Site index: 70 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	41	0	0	0	0	0	0
7	49	0	0	0	0	0	0.6
22	55	58	0.6	100	0	58	3.0
42	60	201	2.2	272	0	201	8.3
63	63	463	5.0	498	0	463	16.9
78	66	808	8.8	703	0	808	27.3
81	68	1,116	12.1	796	0	1,116	35.7
66	70	1,181	12.8	701	2,941	564	36.3
36	71	788	8.6	394	2,480	239	23.4
4	72	109	1.2	46	389	21	3.1
400	--	4,724	51.3	3,510	5,810	3,470	154.6

Age: 26 Site index: 70 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	3	42	0	0	0	0	0	0.1
4	15	50	0	0	0	0	0	1.[illegible]
5	38	56	107	1.2	182	0	107	5.[illegible]
6	67	61	326	3.5	439	0	326	1[illegible].1
7	91	64	682	7.4	732	0	682	24.3
8	103	67	1,088	11.8	945	0	1,088	[illegible]5.9
9	95	69	1,347	14.6	961	0	1,347	42.1
10	66	71	1,194	13.0	709	3,015	571	[illegible]5.8
11	22	73	502	5.5	252	1,595	152	14.6
12								
13								
14								
15								
Totals	500	--	5,246	57.0	4,220	4,610	4,273	172.5

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 26 Site index: 70 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	7	42	0	0	0	0	0	0.3
4	27	52	0	0	0	0	0	2.4
5	59	58	169	1.8	285	0	169	8.1
6	93	62	469	5.1	628	0	469	18.3
7	118	66	908	9.9	973	0	908	31.6
8	123	69	1,337	14.5	1,160	0	1,337	43.1
9	103	71	1,489	16.2	1,061	0	1,489	45.4
10	59	73	1,091	11.9	649	2,794	522	32.0
11	11	74	255	2.8	128	818	77	7.2
12								
13								
14								
15								
Totals	600	--	5,718	62.2	4,884	3,612	4,971	188.4

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

28 Site index: 70 (25-year basis) Density class: 200

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	54	5	0.1	10	0	5	0.3
7	59	33	0.4	45	0	33	1.4
15	62	106	1.2	114	0	106	3.9
24	65	241	2.6	210	0	241	8.3
32	67	436	4.7	312	0	436	14.2
37	68	655	7.1	388	1,614	313	20.4
37	70	818	8.9	408	2,555	247	24.7
30	71	801	8.7	341	2,856	154	23.6
15	72	467	5.1	171	1,797	60	13.5
1	73	25	0.3	8	104	2	0.7
200	--	3,587	39.1	2,007	8,926	1,597	111.0

Age: 28 Site index: 70 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	2	50	0	0	0	0	0	0.2
5	9	56	23	0.3	40	0	23	1.2
6	20	60	98	1.1	132	0	98	4.0
7	35	64	257	2.8	277	0	257	9.3
8	49	66	506	5.5	441	0	506	17.0
9	58	68	803	8.7	573	0	803	25.5
10	58	70	1,036	11.3	615	2,592	495	31.6
11	46	72	1,033	11.2	517	3,263	313	30.5
12	23	73	616	6.7	263	2,216	119	17.7
13	1	74	43	0.5	16	168	6	1.2
14								
15								
Totals	301	--	4,415	48.1	2,874	8,239	2,620	138.2

28 Site index: 70 (25-year basis) Density class: 400

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	42	0	0	0	0	0	0
6	51	0	0	0	0	0	0.6
20	57	56	0.6	95	0	56	2.7
39	61	194	2.1	261	0	194	7.7
60	65	452	4.9	484	0	452	16.0
75	68	803	8.7	697	0	803	26.3
80	70	1,140	12.4	813	0	1,140	35.3
69	72	1,268	13.8	754	3,219	607	37.7
42	73	957	10.4	479	3,053	291	27.6
8	74	221	2.4	94	800	43	6.2
400	--	5,091	55.3	3,677	7,072	3,586	160.1

Age: 28 Site index: 70 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	2	43	0	0	0	0	0	0.1
4	14	52	0	0	0	0	0	1.2
5	36	58	103	1.1	173	0	103	4.9
6	62	63	317	3.4	423	0	317	12.2
7	87	66	672	7.3	719	0	672	23.2
8	100	69	1,096	11.9	950	0	1,096	35.0
9	96	71	1,407	15.3	1,003	0	1,407	42.6
10	71	73	1,339	14.6	795	3,445	641	38.9
11	30	75	700	7.6	352	2,255	213	19.7
12	1	76	32	0.3	13	115	6	0.9
13								
14								
15								
Totals	499	--	5,666	61.5	4,428	5,815	4,455	178.7

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 30 Site index: 70 (25-year basis) Density class: 200

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4								
5	2	56	5	0.1	9	0	5	0.3
6	7	60	32	0.3	43	0	32	1.3
7	14	64	102	1.1	110	0	102	3.7
8	22	66	235	2.5	204	0	235	7.8
9	31	68	428	4.7	306	0	428	13.5
10	36	70	653	7.1	388	1,638	312	19.8
11	37	72	835	9.1	418	2,642	253	24.6
12	31	73	858	9.3	366	3,089	166	24.6
13	18	74	579	6.3	212	2,247	75	16.3
14	2	75	75	0.8	23	308	6	2.1
15								
Totals	200	--	3,802	41.3	2,079	9,924	1,614	114.0

Age: 30 Site index: 70 (25-year basis) Density class

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3							
4	2	51	0	0	0	0	0
5	[illegible]	57	23	0.2	38	0	23
6	19	62	94	1.0	127	0	94
7	33	65	250	2.7	268	0	250
8	46	68	497	5.4	431	0	497
9	56	70	800	8.7	571	0	800
10	58	72	1,059	11.5	629	2,695	507
11	48	73	1,108	12.0	555	3,540	337
12	27	75	757	8.2	324	2,747	147
13	3	76	109	1.2	40	424	14
14							
15							
Totals	300	--	4,697	50.9	2,983	9,406	2,669

Age: 30 Site index: 70 (25-year basis) Density class: 400

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	43	0	0	0	0	0	0
4	6	52	0	0	0	0	0	0.5
5	19	58	54	0.6	91	0	54	2.5
6	37	63	188	2.0	252	0	188	7.3
7	57	67	442	4.8	472	0	442	15.2
8	73	69	797	8.7	690	0	797	25.3
9	79	72	1,156	12.6	824	0	1,156	34.8
10	71	74	1,335	14.5	794	3,444	640	38.6
11	47	75	1,099	11.9	552	3,544	334	30.8
12	12	76	355	3.9	152	1,299	69	9.7
13								
14								
15								
Totals	402	--	5,426	59.0	3,827	8,287	3,680	164.7

Age: 30 Site index: 70 (25-year basis) Density clas

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	2	44	0	0	0	0	0
4	13	53	0	0	0	0	0
5	33	60	100	1.1	165	0	100
6	59	64	309	3.4	410	0	309
7	83	68	663	7.2	706	0	663
8	98	71	1,100	12.0	952	0	1,100
9	97	73	1,452	15.8	1,035	0	1,452
10	76	75	1,457	15.8	866	3,808	699
11	37	77	883	9.6	444	2,876	269
12	3	78	86	0.9	37	315	17
13							
14							
15							
Totals	501	--	6,050	65.8	4,615	6,999	4,609

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 10 Site index: 80 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	28	0	0	0	0	0	0
13	31	14	0.1	36	0	0	1.8
44	34	98	1.1	164	0	0	8.6
69	36	253	2.8	306	0	0	18.5
59	37	318	3.5	293	0	0	20.7
14	38	104	1.1	76	0	0	6.3
200	--	787	8.6	875	0	0	55.9

Age: 10 Site index: 80 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	10	28	0	0	0	0	0	0.9
5	53	32	59	0.6	153	0	0	7.2
6	99	34	229	2.5	380	0	0	19.5
7	98	36	370	4.0	445	0	0	26.2
8	39	38	214	2.3	197	0	0	13.6
9								
10								
11								
12								
13								
14								
15								
Totals	299	--	872	9.4	1,175	0	0	67.4

: 10 Site index: 80 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	24	0	0	0	0	0	0.1
36	29	0	0	0	0	0	3.1
105	32	121	1.3	307	0	0	14.3
140	35	334	3.6	547	0	0	27.6
98	37	379	4.1	453	0	0	26.1
19	39	107	1.2	98	0	0	6.6
400	--	941	10.2	1,405	0	0	77.8

Age: 10 Site index: 80 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	10	24	0	0	0	0	0	0.5
4	74	30	0	0	0	0	0	6.5
5	154	33	185	2.0	458	0	0	20.9
6	164	36	401	4.4	651	0	0	32.1
7	88	38	352	3.8	418	0	0	23.6
8	11	40	62	0.7	57	0	0	3.7
9								
10								
11								
12								
13								
14								
15								
Totals	501	--	1,000	10.9	1,584	0	0	87.3

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 10 Site index: 80 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	26	25	0	0	0	0	0	1.3
4	117	30	0	0	0	0	0	10.2
5	193	34	243	2.6	586	0	0	26.3
6	176	37	445	4.8	714	0	0	34.5
7	81	39	330	3.6	390	0	0	21.5
8	8	40	47	0.5	43	0	0	2.7
9								
10								
11								
12								
13								
14								
15								
Totals	601	--	1,065	11.5	1,733	0	0	96.5

Age: 10 Site index: 80 (25-year basis) Density clas

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2	1	18	0	0	0	0	0
3	49	26	0	0	0	0	0
4	159	31	0	0	0	0	0
5	224	35	294	3.2	694	0	0
6	183	38	478	5.2	760	0	0
7	77	40	323	3.5	379	0	0
8	7	41	45	0.5	41	0	0
9							
10							
11							
12							
13							
14							
15							
Totals	700	--	1,140	12.4	1,874	0	0

Age: 10 Site index: 80 (25-year basis) Density class: 800

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	5	18	0	0	0	0	0	0.1
3	76	26	0	0	0	0	0	3.7
4	198	32	0	0	0	0	0	17.2
5	249	36	339	3.7	786	0	0	34.0
6	188	38	507	5.5	798	0	0	37.0
7	76	41	328	3.6	384	0	0	20.3
8	8	42	51	0.6	47	0	0	2.9
9								
10								
11								
12								
13								
14								
15								
Totals	800	--	1,225	13.4	2,015	0	0	115.2

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 12 Site index: 80 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
6	37	9	0.1	19	0	9	0.8
22	40	65	0.7	99	0	65	4.4
43	43	200	2.2	231	0	200	11.6
57	44	375	4.1	338	0	375	19.7
50	46	451	4.9	325	0	451	22.1
21	47	249	2.7	147	417	116	11.6
199	--	1,349	14.7	1,159	417	1,216	70.2

Age: 12 Site index: 80 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	4	34	0	0	0	0	0	0.4
5	27	38	41	0.4	89	0	41	3.6
6	60	41	180	2.0	274	0	180	11.9
7	85	44	400	4.3	459	0	400	22.6
8	80	45	542	5.9	488	0	542	27.8
9	41	47	379	4.1	273	0	379	18.2
10	3	48	36	0.4	21	63	17	1.7
11								
12								
13								
14								
15								
Totals	300	--	1,578	17.1	1,604	63	1,559	86.2

: 12 Site index: 80 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	29	0	0	0	0	0	0
18	35	0	0	0	0	0	1.5
60	39	95	1.0	204	0	0	8.1
102	42	313	3.4	474	0	0	20.1
114	45	556	6.0	636	0	0	30.6
82	46	571	6.2	512	0	0	28.5
23	48	221	2.4	159	0	0	10.3
400	--	1,756	19.0	1,985	0	0	99.1

Age: 12 Site index: 80 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	5	29	0	0	0	0	0	0.2
4	40	36	0	0	0	0	0	3.5
5	98	40	162	1.8	341	0	0	13.4
6	139	43	439	4.8	658	0	0	27.3
7	131	46	656	7.1	746	0	0	35.1
8	74	47	533	5.8	476	0	0	25.9
9	13	49	123	1.3	89	0	0	5.6
10								
11								
12								
13								
14								
15								
Totals	500	--	1,913	20.8	2,310	0	0	111.0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 12 Site index: 80 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	13	30	0	0	0	0	0	0.6
4	68	36	0	0	0	0	0	6.0
5	137	41	234	2.5	484	0	0	18.6
6	169	44	548	6.0	815	0	0	33.1
7	139	47	714	7.8	810	0	0	37.2
8	66	48	485	5.3	433	0	0	23.0
9	8	50	78	0.9	56	0	0	3.5
10								
11								
12								
13								
14								
15								
Totals	600	--	2,059	22.5	2,598	0	0	122.0

Age: 12 Site index: 80 (25-year basis) Density class

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2	1	21	0	0	0	0	0
3	27	31	0	0	0	0	0
4	100	37	0	0	0	0	0
5	172	42	307	3.3	623	0	0
6	192	45	641	7.0	946	0	0
7	143	48	751	8.2	848	0	0
8	60	50	449	4.9	400	0	0
9	6	51	60	0.7	43	0	0
10							
11							
12							
13							
14							
15							
Totals	701	--	2,208	24.1	2,860	0	0

Age: 12 Site index: 80 (25-year basis) Density class: 800

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	3	21	0	0	0	0	0	0.1
3	45	31	0	0	0	0	0	2.2
4	134	38	0	0	0	0	0	11.7
5	205	43	377	4.1	756	0	0	27.9
6	209	46	720	7.8	1,054	0	0	41.0
7	144	49	780	8.5	877	0	0	38.5
8	56	51	431	4.7	383	0	0	19.4
9	5	52	55	0.6	40	0	0	2.3
10								
11								
12								
13								
14								
15								
Totals	801	--	2,363	25.7	3,110	0	0	143.1

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

14 Site index: 80 (25-year basis) Density class: 200

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
4	42	6	0.1	17	0	6	0.5
14	46	49	0.5	72	0	49	2.8
30	48	162	1.8	182	0	162	8.0
44	50	342	3.7	304	0	342	15.5
50	52	520	5.6	374	0	520	22.1
41	54	549	6.0	324	1,091	258	22.3
17	55	279	3.0	138	755	82	10.9
200	--	1,907	20.7	1,407	1,846	1,419	82.1

Age: 14 Site index: 80 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	3	39	0	0	0	0	0	0.2
5	17	44	32	0.3	6[illegible]	0	32	2.[illegible]
6	42	47	146	1.6	213	0	146	8.1
7	66	50	363	3.9	406	0	363	17.5
8	76	52	605	6.6	537	0	605	26.7
9	65	53	688	7.5	494	0	688	28.6
10	30	55	419	4.6	247	854	198	16.6
11	2	56	29	0.3	14	79	9	1.1
12								
13								
14								
15								
Totals	301	--	2,282	24.8	1,974	933	2,041	101.1

14 Site index: 80 (25-year basis) Density class: 400

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	33	0	0	0	0	0	0
11	40	0	0	0	0	0	1.0
40	44	78	0.9	153	0	78	5.5
76	48	275	3.0	397	0	275	14.9
100	51	567	6.2	632	0	567	26.7
97	53	783	8.5	693	0	783	33.7
62	55	675	7.3	485	0	675	27.3
14	56	203	2.2	120	423	96	7.9
401	--	2,581	28.1	2,480	423	2,474	117.0

Age: 14 Site index: 80 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	3	34	0	0	0	0	0	0.1
4	26	40	0	0	0	0	0	2.3
5	69	46	141	1.5	271	0	141	9.5
6	111	49	416	4.5	596	0	416	21.8
7	128	52	743	8.1	826	0	743	34.1
8	105	54	874	9.5	772	0	874	36.7
9	52	56	580	6.3	416	0	580	22.9
10	6	57	87	0.9	51	184	41	3.3
11								
12								
13								
14								
15								
Totals	500	--	2,841	30.8	2,932	184	2,795	130.7

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 14 Site index: 80 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	8	34	0	0	0	0	0	0.4
4	46	42	0	0	0	0	0	4.1
5	102	46	214	2.3	405	0	214	13.9
6	144	50	554	6.0	788	0	554	28.3
7	148	53	884	9.6	978	0	884	39.5
8	106	55	908	9.9	801	0	908	37.2
9	42	57	482	5.2	345	0	482	18.6
10	3	58	39	0.4	24	86	19	1.5
11								
12								
13								
14								
15								
Totals	599	--	3,081	33.4	3,341	86	3,061	143.5

Age: 14 Site index: 80 (25-year basis) Density cl

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	18	35	0	0	0	0	0
4	71	42	0	0	0	0	0
5	135	48	294	3.2	549	0	294
6	173	51	684	7.4	1,219	0	684
7	162	54	994	10.8	1,095	0	994
8	105	56	914	9.9	805	0	914
9	35	58	407	4.4	292	0	407
10	1	60	22	0.2	13	48	10
11							
12							
13							
14							
15							
Totals	700	--	3,315	35.9	3,973	48	3,303

Age: 14 Site index: 80 (25-year basis) Density class: 800

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2	2	24	0	0	0	0	0	0
3	31	36	0	0	0	0	0	1.5
4	98	43	0	0	0	0	0	8.6
5	168	49	376	4.1	692	0	376	22.8
6	198	52	804	8.7	1,129	0	804	38.8
7	171	56	1,081	11.7	1,188	0	1,081	45.8
8	102	58	911	9.9	801	0	911	35.5
9	30	60	360	3.9	258	0	360	13.2
10	1	61	15	0.2	9	35	7	0.5
11								
12								
13								
14								
15								
Totals	801	--	3,547	38.5	4,077	35	3,539	166.7

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

: 16 Site index: 80 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	47	5	0.1	10	0	5	0.3
10	51	41	0.4	58	0	41	2.1
23	54	138	1.5	153	0	138	6.1
36	56	309	3.4	272	0	309	12.5
45	58	516	5.6	369	0	516	19.7
44	59	658	7.2	390	1,444	312	24.1
31	60	581	6.3	289	1,675	173	20.5
8	61	191	2.1	81	643	36	6.6
199	--	2,439	26.6	1,622	3,762	1,530	91.9

Age: 16 Site index: 80 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	2	43	0	0	0	0	0	0.2
5	12	48	27	0.3	50	0	27	1.7
6	31	52	125	1.4	176	0	125	6.2
7	53	55	327	3.6	361	0	327	14.1
8	68	57	598	6.5	526	0	598	23.7
9	68	59	808	8.8	579	0	808	30.1
10	49	60	755	8.2	447	1,688	358	26.9
11	16	62	315	3.4	156	914	94	10.8
12								
13								
14								
15								
Totals	299	--	2,955	32.2	2,295	2,602	2,337	113.7

: 16 Site index: 80 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
8	44	0	0	0	0	0	0.7
30	49	68	0.7	124	0	68	4.1
60	53	245	2.7	343	0	245	11.7
85	56	544	5.9	596	0	544	22.8
94	58	852	9.3	749	0	852	32.9
78	60	951	10.3	681	0	951	34.6
40	62	627	6.8	372	1,430	298	21.9
4	63	85	0.9	42	251	25	2.9
399	--	3,372	36.6	2,907	1,681	2,983	131.6

Age: 16 Site index: 80 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	2	37	0	0	0	0	0	0.1
4	19	45	0	0	0	0	0	1.7
5	53	50	125	1.4	226	0	125	7.3
6	91	54	386	4.2	537	0	386	17.9
7	116	57	755	8.2	825	0	755	30.9
8	112	60	1,041	11.3	913	0	1,041	39.2
9	78	62	973	10.6	696	0	973	34.6
10	28	63	442	4.8	262	1,026	210	15.0
11	1	64	14	0.1	7	41	4	0.4
12								
13								
14								
15								
Totals	500	--	3,736	40.6	3,466	1,067	3,494	147.1

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 16 Site index: 80 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	6	38	0	0	0	0	0	0.3
4	35	46	0	0	0	0	0	3.0
5	81	51	196	2.1	350	0	196	11.0
6	123	55	535	5.8	740	0	535	24.2
7	141	58	946	10.3	1,031	0	946	37.7
8	123	61	1,168	12.7	1,022	0	1,168	42.9
9	73	63	930	10.1	665	0	930	32.2
10	18	64	296	3.2	175	698	141	9.8
11								
12								
13								
14								
15								
Totals	600	--	4,071	44.2	3,983	698	3,916	161.1

Age: 16 Site index: 80 (25-year basis) Density cl

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	13	39	0	0	0	0	0
4	55	47	0	0	0	0	0
5	110	52	276	3.0	488	0	276
6	153	57	685	7.4	941	0	685
7	162	60	1,112	12.1	1,207	0	1,112
8	128	62	1,248	13.6	1,090	0	1,248
9	66	64	865	9.4	618	0	865
10	12	66	204	2.2	121	490	97
11							
12							
13							
14							
15							
Totals	699	--	4,390	47.7	4,465	490	4,283

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

18 Site index: 80 (25-year basis) Density class: 200

rees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	51	5	0	8	0	5	0.3
8	55	35	0.4	49	0	35	1.6
18	58	123	1.3	133	0	123	5.0
30	60	283	3.1	248	0	283	10.5
40	62	498	5.4	356	0	498	17.5
43	64	695	7.6	412	1,624	330	23.4
37	65	743	8.1	370	2,238	223	24.2
20	66	492	5.3	209	1,707	94	15.6
2	67	53	0.6	19	201	7	1.7
200	--	2,927	31.8	1,804	5,770	1,598	99.8

Age: 18 Site index: 80 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	2	46	0	0	0	0	0	0.1
5	10	52	24	0.3	42	0	24	1.3
6	25	56	111	1.2	153	0	111	5.0
7	44	59	300	3.3	326	0	300	11.8
8	60	62	576	6.3	504	0	576	21.0
9	66	64	849	9.2	607	0	849	29.2
10	57	65	944	10.3	560	2,245	450	31.1
11	32	66	666	7.2	332	2,028	200	21.2
12	4	68	109	1.2	46	382	21	3.4
13								
14								
15								
Totals	300	--	3,579	39.0	2,570	4,655	2,531	124.1

18 Site index: 80 (25-year basis) Density class: 400

rees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
6	47	0	0	0	0	0	0.5
24	53	60	0.7	106	0	60	3.2
49	57	223	2.4	306	0	223	9.7
74	60	516	5.6	559	0	516	19.8
88	63	868	9.4	758	0	868	30.8
83	65	1,098	11.9	784	0	1,098	36.8
57	67	966	10.5	573	2,335	461	31.0
18	68	380	4.1	190	1,170	115	11.8
399	--	4,111	44.6	3,276	3,505	3,341	143.6

Age: 18 Site index: 80 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood: Volume		All trees as pulpwood: 5.25-foot bolts	Multiple products: Saw-timber	Multiple products: Pulp-wood	Basal area
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	2	40	0	0	0	0	0	0.1
4	15	48	0	0	0	0	0	1.3
5	43	54	113	1.2	197	0	113	5.9
6	78	58	360	3.9	490	0	360	15.2
7	104	62	743	8.1	803	0	743	27.8
8	111	64	1,119	12.2	975	0	1,119	38.7
9	91	66	1,231	13.4	880	0	1,231	40.3
10	49	68	850	9.2	505	2,086	406	26.7
11	8	70	163	1.8	81	509	49	5.0
12								
13								
14								
15								
Totals	501	--	4,579	49.8	3,931	2,595	4,021	161.0

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 18 Site index: 80 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	5	41	0	0	0	0	0	0.2
4	28	49	0	0	0	0	0	2.4
5	67	55	181	2.0	311	0	181	9.1
6	107	60	512	5.6	693	0	512	21.1
7	132	63	963	10.5	1,037	0	963	35.1
8	127	66	1,317	14.3	1,145	0	1,317	44.5
9	92	68	1,276	13.9	912	0	1,276	40.8
10	39	70	693	7.5	411	1,726	331	21.2
11	3	71	63	0.7	31	198	19	1.9
12								
13								
14								
15								
Totals	600	--	5,005	54.5	4,540	1,924	4,599	176.3

Age: 18 Site index: 80 (25-year basis) Density cla

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	10	42	0	0	0	0	0
4	45	50	0	0	0	0	0
5	94	57	260	2.8	443	0	260
6	137	61	671	7.3	904	0	671
7	155	64	1,167	12.7	1,253	0	1,167
8	138	67	1,468	16.0	1,274	0	1,468
9	90	69	1,267	13.8	904	0	1,267
10	30	71	551	6.0	327	1,393	263
11	1	73	24	0.3	11	75	7
12							
13							
14							
15							
Totals	700	--	5,408	58.9	5,116	1,468	5,103

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

20 Site index: 80 (25-year basis) Density class: 200

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
2	54	4	0	7	0	4	0.2
7	58	32	0.3	43	0	32	1.4
16	61	112	1.2	120	0	112	4.2
26	64	263	2.9	230	0	263	9.2
36	66	478	5.2	342	0	478	15.8
41	68	703	7.6	417	1,719	336	22.2
38	69	830	9.0	415	2,577	251	25.4
27	70	707	7.7	300	2,513	136	21.1
8	71	244	2.7	89	936	31	7.1
201	--	3,373	36.6	1,963	7,745	1,643	106.6

Age: 20 Site index: 80 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	1	49	0	0	0	0	0	0.1
5	8	55	21	0.2	27	0	21	1.1
6	21	59	101	1.1	148	0	101	4.2
7	38	63	278	3.0	300	0	278	10.2
8	54	65	553	6.0	481	0	553	18.8
9	62	67	859	9.3	612	0	859	27.6
10	59	69	1,050	11.4	624	2,605	501	32.4
11	42	71	923	10.0	462	2,899	280	27.6
12	14	72	367	4.0	156	1,314	71	10.7
13								
14								
15								
Totals	299	--	4,152	45.0	2,810	6,818	2,664	132.7

20 Site index: 80 (25-year basis) Density class: 400

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
5	50	0	0	0	0	0	0.4
20	56	55	0.6	94	0	55	2.7
42	61	206	2.2	278	0	206	8.3
66	64	490	5.3	526	0	490	17.6
82	67	862	9.4	750	0	862	28.6
84	69	1,176	12.8	840	0	1,176	36.9
66	71	1,198	13.0	712	3,017	573	36.1
32	72	731	7.9	365	2,319	222	21.3
3	74	77	0.8	33	278	15	2.2
400	--	4,795	52.0	3,598	5,614	3,599	154.1

Age: 20 Site index: 80 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	42	0	0	0	0	0	0.1
4	12	51	0	0	0	0	0	1.1
5	37	58	105	1.1	177	0	105	5.0
6	68	62	338	3.7	454	0	338	13.3
7	94	66	723	7.9	775	0	723	25.3
8	107	68	1,152	12.5	999	0	1,152	37.3
9	97	70	1,395	15.2	995	0	1,395	42.8
10	64	72	1,183	12.9	703	3,022	566	34.8
11	20	74	459	5.0	230	1,469	139	13.1
12								
13								
14								
15								
Totals	500	--	5,355	58.3	4,333	4,491	4,418	172.8

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 20　　Site index: 80 (25-year basis)　　Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	4	43	0	0	0	0	0	0.2
4	23	52	0	0	0	0	0	2.0
5	58	59	169	1.8	282	0	169	7.9
6	95	64	489	5.3	654	0	489	18.7
7	122	67	959	10.4	1,024	0	959	32.7
8	127	70	1,402	15.2	1,216	0	1,402	44.3
9	103	72	1,524	16.6	1,086	0	1,524	45.6
10	57	74	1,077	11.7	640	2,787	516	30.9
11	11	76	252	2.7	126	815	77	7.0
12								
13								
14								
15								
Totals	600	--	5,872	63.7	5,028	3,602	5,136	189.3

Age: 20　　Site index: 80 (25-year basis)　　Density cl

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	8	44	0	0	0	0	0
4	38	54	0	0	0	0	0
5	81	60	246	2.7	407	0	246
6	124	65	652	7.1	866	0	652
7	148	69	1,189	12.9	1,267	0	1,189
8	142	71	1,609	17.5	1,391	0	1,609
9	105	74	1,584	17.2	1,128	0	1,584
10	48	76	939	10.2	559	2,464	450
11	6	77	135	1.5	68	441	41
12							
13							
14							
15							
Totals	700	--	6,354	69.1	5,686	2,905	5,771

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

22 Site index: 80 (25-year basis) Density class: 200

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	56	4	0	7	0	4	0.2
6	61	29	0.3	40	0	29	1.2
14	64	104	1.1	111	0	104	3.7
23	67	248	2.7	215	0	248	8.2
33	69	461	5.0	329	0	461	14.4
38	71	701	7.6	416	1,771	335	21.0
39	73	877	9.5	439	2,789	266	25.5
31	74	851	9.2	364	3,076	165	24.1
14	75	480	5.2	177	1,869	62	13.3
1	76	23	0.3	7	96	2	0.6
200	--	3,778	40.9	2,105	9,601	1,676	112.2

Age: 22 Site index: 80 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	1	52	0	0	0	0	0	0.1
5	7	58	20	0.2	33	0	20	0.9
6	19	62	94	1.0	125	0	94	3.7
7	34	66	262	2.8	280	0	262	9.1
8	49	69	532	5.8	462	0	532	17.1
9	59	71	856	9.3	611	0	856	26.1
10	60	73	1,109	12.1	659	2,842	531	32.5
11	47	74	1,101	12.0	552	3,536	335	31.2
12	23	76	653	7.1	279	2,379	127	18.1
13	2	77	52	0.6	19	202	7	1.4
14								
15								
Totals	301	--	4,679	50.9	3,020	8,959	2,764	140.2

22 Site index: 80 (25-year basis) Density class: 400

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
4	53	0	0	0	0	0	0.4
17	59	51	0.6	85	0	51	2.3
37	64	193	2.1	257	0	193	7.3
59	67	468	5.1	500	0	468	15.9
76	70	850	9.2	735	0	850	26.7
82	72	1,217	13.2	868	0	1,217	36.2
71	74	1,355	14.7	806	3,518	649	38.7
43	76	1,028	11.2	516	3,332	313	28.5
9	77	264	2.9	113	968	51	7.1
398	--	5,426	59.0	3,880	7,818	3,792	163.1

Age: 22 Site index: 80 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	44	0	0	0	0	0	0.1
4	11	54	0	0	0	0	0	0.9
5	32	60	98	1.1	161	0	98	4.4
6	60	65	320	3.5	425	0	320	11.9
7	87	69	702	7.6	747	0	702	23.2
8	102	72	1,163	12.6	1,006	0	1,163	35.6
9	99	74	1,500	16.3	1,068	0	1,500	43.6
10	74	76	1,437	15.6	854	3,780	689	40.1
11	32	78	793	8.6	398	2,594	242	21.5
12	2	79	62	0.7	27	229	12	1.6
13								
14								
15								
Totals	500	--	6,075	66.0	4,686	6,603	4,726	182.9

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 22 Site index: 80 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	3	46	0	0	0	0	0	0.2
4	20	55	0	0	0	0	0	1.8
5	51	62	159	1.7	260	[illegible]	159	6.9
6	86	67	469	5.1	619	0	469	16.9
7	114	70	948	10.3	1,007	0	948	30.5
8	124	73	1,450	15.8	1,251	0	1,450	43.4
9	109	76	1,700	18.5	1,211	0	1,700	48.2
10	70	78	1,402	15.2	834	3,733	673	38.2
11	22	79	538	5.8	270	1,775	164	14.2
12								
13								
14								
15								
Totals	599	--	6,666	72.4	5,452	5,508	5,563	200.3

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

24 Site index: 80 (25-year basis) Density class: 200

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	59	4	0	6	0	4	0.2
5	64	27	0.3	36	0	27	1.0
12	67	97	1.1	104	0	97	3.3
21	70	236	2.6	204	0	236	7.4
30	72	445	4.8	317	0	445	13.3
37	74	694	7.5	412	1,799	333	19.9
38	76	904	9.8	454	2,927	275	25.1
33	77	948	10.3	405	3,474	184	25.7
19	78	674	7.3	248	2,651	88	17.9
3	79	119	1.3	38	494	10	3.1
199	--	4,148	45.0	2,224	11,345	1,699	116.9

Age: 24 Site index: 80 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	1	54	0	0	0	0	0	0.1
5	6	60	18	0.2	31	0	18	0.8
6	17	65	88	1.0	116	0	88	[illegible]
7	31	69	248	2.7	264	0	248	8.2
8	45	72	514	5.6	445	0	514	15.8
9	56	74	847	9.2	603	0	847	24.7
10	59	76	1,143	12.4	679	3,002	548	32.0
11	50	77	1,225	13.3	615	4,002	[illegible]	[illegible]
12	30	79	891	9.7	383	3,288	174	23.6
13	5	80	184	2.0	68	729	24	4.8
14								
15								
Totals	300	--	5,158	56.1	3,204	11,021	2,834	146.6

24 Site index: 80 (25-year basis) Density class: 400

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
4	55	0	0	0	0	0	0.3
15	62	48	0.5	78	0	48	2.1
34	66	182	2.0	241	0	182	6.6
54	70	449	4.9	477	0	449	14.5
72	73	834	9.1	721	0	834	25.0
80	76	1,237	13.4	880	0	1,237	35.2
73	78	1,462	15.9	870	3,887	702	40.0
51	79	1,262	13.7	633	4,160	385	33.5
17	80	520	5.6	223	1,931	102	13.5
400	--	5,994	65.1	4,123	9,978	3,939	170.7

Age: 24 Site index: 80 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	46	0	0	0	0	0	0
4	9	56	0	0	0	0	0	0.8
5	29	63	92	1.0	150	0	92	[illegible]
6	55	68	306	3.3	402	0	306	10.8
7	80	72	683	7.4	722	0	683	21.5
8	98	75	1,163	12.6	1,002	0	1,163	34.1
9	99	77	1,569	17.0	1,117	0	1,569	43.6
10	80	79	1,628	17.7	969	4,380	782	[illegible]
11	43	81	1,097	11.9	552	3,649	336	28.5
12	6	82	198	2.2	85	742	[illegible]	5.0
13								
14								
15								
Totals	500	--	6,736	73.1	4,999	8,771	4,970	191.7

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 24 Site index: 80 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	3	47	0	0	0	0	0	0.1
4	18	57	0	0	0	0	0	1.6
5	46	64	151	1.6	243	0	151	6.2
6	79	70	452	4.9	591	0	452	15.5
7	107	73	933	10.1	985	0	933	28.7
8	121	76	1,476	16.0	1,271	0	1,476	42.2
9	112	79	1,826	19.8	1,299	0	1,826	49.6
10	80	81	1,666	18.1	991	4,535	801	43.5
11	33	83	850	9.2	428	2,850	260	21.5
12	2	84	53	0.6	23	198	10	1.3
13								
14								
15								
Totals	601	--	7,407	80.3	5,831	7,583	5,909	210.2

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

26 Site index: 80 (25-year basis) Density class: 200

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	61	3	0	6	0	3	0.1
5	66	26	0.3	34	0	26	0.9
11	70	93	1.0	98	0	93	3.0
20	72	226	2.5	195	0	226	6.9
28	75	432	4.7	307	0	432	12.4
35	77	686	7.5	408	1,813	329	19.0
37	78	919	10.0	462	3,019	281	24.6
34	80	1,016	11.0	436	3,762	198	26.6
23	81	824	9.0	304	3,267	108	21.1
6	82	261	2.8	85	1,095	21	6.6
200	--	4,486	48.8	2,335	12,956	1,717	121.2

Age: 26 Site index: 80 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	1	56	0	0	0	0	0	0.1
5	6	62	17	0.2	28	0	17	0.7
6	15	67	83	0.9	110	0	83	3.0
7	28	71	238	2.6	251	0	238	7.6
8	42	74	498	5.4	429	0	498	14.7
9	53	76	837	9.1	595	0	837	23.5
10	58	78	1,163	12.6	692	[illegible]	558	31.4
11	52	80	1,313	14.3	661	[illegible]	401	34.4
12	35	82	1,080	11.7	464	4,027	211	27.6
13	10	83	370	4.0	136	[illegible]	49	[illegible]
14								
15								
Totals	300	--	5,599	60.8	3,366	12,962	2,892	[illegible]

26 Site index: 80 (25-year basis) Density class: 400

rees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
umber	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
4	57	0	0	0	0	0	0.3
14	64	45	0.5	73	0	45	1.9
31	69	174	1.9	228	0	174	6.0
50	73	434	4.7	458	0	434	13.5
68	76	819	8.9	706	0	819	23.7
77	78	1,246	13.5	886	0	1,246	34.2
74	80	[illegible]	16.7	914	4,163	739	40.5
56	82	1,444	15.7	727	4,826	442	37.0
25	83	780	8.5	336	2,928	153	19.5
1	85	[illegible]	0.5	17	174	6	1.1
400	--	6,522	70.9	4,345	12,091	4,058	177.7

Age: 26 Site index: 80 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	48	0	0	0	0	0	0
4	9	58	0	0	0	0	0	0.7
5	26	65	88	1.0	140	0	88	3.6
6	50	70	294	3.2	383	0	294	9.9
7	75	74	665	7.2	701	0	665	20.2
8	94	78	1,157	12.6	996	0	1,157	32.6
9	98	80	1,613	17.5	1,147	0	1,613	43.2
10	84	82	1,772	19.3	1,055	4,856	853	45.7
11	51	84	1,358	14.8	683	4,575	416	33.9
12	12	85	394	4.3	169	1,488	77	9.6
13								
14								
15								
Totals	500	--	7,341	79.9	5,274	10,919	5,163	199.4

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 26 Site index: 80 (25-year basis) Density class: 600

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	3	49	0	0	0	0	0	0.1
4	16	60	0	0	0	0	0	1.4
5	42	67	145	1.6	230	0	145	5.7
6	73	72	437	4.7	567	0	437	14.4
7	102	76	918	10.0	966	0	918	27.1
8	117	79	1,489	16.2	1,279	0	1,489	41.0
9	114	82	1,917	20.8	1,362	0	1,917	50.1
10	87	84	1,879	20.4	1,117	5,204	905	47.3
11	42	86	1,146	12.5	577	3,894	352	28.0
12	5	87	153	1.7	65	582	30	3.7
13								
14								
15								
Totals	601	--	8,084	87.9	6,163	9,680	6,193	218.8

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

e: 28 Site index: 80 (25-year basis) Density class: 200

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1	63	3	0	5	0	3	0.1
4	68	25	0.3	32	0	25	0.9
11	72	89	1.0	94	0	89	2.8
18	75	218	2.4	188	0	218	6.4
27	77	421	4.6	299	0	421	11.7
33	79	677	7.4	403	1,820	325	18.1
37	81	927	10.1	467	3,082	284	24.1
34	82	1,064	11.6	457	3,977	208	27.0
25	83	939	10.2	348	3,751	124	23.3
10	84	426	4.6	137	1,794	35	10.4
200	--	4,789	52.2	2,430	14,424	1,732	124.8

Age: 28 Site index: 80 (25-year basis) Density class: 300

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	1	57	0	0	0	0	0	0.1
5	5	64	17	0.2	27	0	17	0.7
6	14	69	80	0.9	105	0	80	2.7
7	26	73	229	2.5	242	0	229	7.0
8	40	76	484	5.3	417	0	484	13.9
9	51	79	826	9.0	588	0	826	22.5
10	56	81	1,174	12.8	698	3,192	564	30.7
11	53	83	1,376	15.0	692	4,611	422	34.9
12	39	84	1,229	13.4	530	4,623	241	30.4
13	15	85	575	6.3	214	2,310	76	14.0
14								
15								
Totals	300	--	5,990	65.4	3,513	14,736	2,939	156.9

e: 28 Site index: 80 (25-year basis) Density class: 400

Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
		Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
3	59	0	0	0	0	0	0.3
13	66	43	0.5	69	0	43	1.7
29	71	167	1.8	218	0	167	5.6
47	75	420	4.6	443	0	420	12.6
65	78	805	8.7	692	0	805	22.5
75	81	1,249	13.6	888	0	1,249	33.2
75	83	1,590	17.3	946	4,374	765	40.6
60	84	1,587	17.3	801	5,363	487	39.4
31	86	1,013	11.0	436	3,836	199	24.5
3	87	131	1.4	49	529	17	3.1
401	--	7,005	76.2	4,542	14,102	4,152	183.5

Age: 28 Site index: 80 (25-year basis) Density class: 500

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3	1	50	0	0	0	0	0	0
4	8	60	0	0	0	0	0	0.7
5	24	67	84	0.9	133	0	84	3.3
6	47	73	283	3.1	367	0	283	9.2
7	71	77	649	7.1	683	0	649	19.0
8	90	80	1,149	12.5	987	0	1,149	31.4
9	96	82	1,643	17.9	1,169	0	1,643	42.6
10	86	85	1,883	20.5	1,121	5,236	907	47.0
11	58	86	1,577	17.1	796	5,369	484	38.2
12	19	88	624	6.8	269	2,376	123	14.8
13								
14								
15								
Totals	500	--	7,892	85.9	5,525	12,981	5,322	206.2

Table 1.--Per-acre yield estimates for old-field slash pine plantations by diameter distribution frequencies (continued)

Age: 30 Site index: 80 (25-year basis) Density class: 200

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4								
5	1	64	3	0	5	0	3	0.1
6	4	70	24	0.3	31	0	24	0.8
7	10	74	86	0.9	90	0	86	2.6
8	17	77	211	2.3	182	0	211	6.0
9	25	79	411	4.5	292	0	411	11.1
10	32	81	669	7.3	399	1,822	322	17.4
11	36	83	931	10.1	469	3,126	285	23.5
12	34	84	1,099	11.9	473	4,139	216	27.1
13	27	86	1,030	11.2	382	4,137	136	24.9
14	13	87	578	6.3	187	2,448	48	13.7
15	1	88	29	0.3	7	125	2	0.7
Totals	200	--	5,071	55.1	2,517	15,797	1,744	127.9

Age: 30 Site index: 80 (25-year basis) Density c

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple product	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft
1							
2							
3							
4	1	59	0	0	0	0	0
5	5	66	16	0.2	25	0	16
6	13	71	77	0.8	100	0	77
7	25	75	221	2.4	233	0	221
8	38	78	472	5.1	406	0	472
9	49	81	815	8.9	579	0	815
10	55	83	1,179	12.8	701	3,249	567
11	53	85	1,423	15.5	718	4,814	437
12	41	86	1,347	14.6	582	5,106	265
13	20	88	765	8.3	284	3,090	102
14	1	89	47	0.5	15	201	4
15							
Totals	301	--	6,362	69.1	3,643	16,460	2,976

Age: 30 Site index: 80 (25-year basis) Density class: 400

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products		Basal area
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood	
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.	Sq. ft.
1								
2								
3								
4	3	60	0	0	0	0	0	0.2
5	12	68	42	0.5	66	0	42	1.6
6	27	73	161	1.8	209	0	161	5.2
7	45	77	409	4.4	429	0	409	11.9
8	62	80	791	8.6	680	0	791	21.5
9	73	83	1,248	13.6	887	0	1,248	32.2
10	74	85	1,629	17.7	970	4,537	785	40.5
11	62	87	1,701	18.5	858	5,799	523	41.1
12	36	88	1,215	13.2	525	4,632	240	28.6
13	6	90	255	2.8	95	1,034	74	5.9
14								
15								
Totals	400	--	7,451	81.1	4,719	16,002	4,273	188.7

Age: 30 Site index: 80 (25-year basis) Density cl

D.b.h. class (Inches)	Trees	Mean tree height (total)	All trees as pulpwood			Multiple products	
			Volume		5.25-foot bolts	Saw-timber	Pulp-wood
	Number	Feet	Cu. ft.	Cords	Number	Bd. ft.	Cu. ft.
1							
2							
3	1	51	0	0	0	0	0
4	7	62	0	0	0	0	0
5	22	69	81	0.9	127	0	81
6	44	74	274	3.0	354	0	274
7	68	79	635	6.9	665	0	635
8	87	82	1,139	12.4	977	0	1,139
9	95	85	1,662	18.1	1,181	0	1,662
10	88	87	1,969	21.4	1,172	5,543	949
11	63	89	1,759	19.1	889	6,045	542
12	25	90	855	9.3	370	3,281	169
13	1	92	28	0.3	11	115	4
14							
15							
Totals	501	--	8,402	91.4	5,746	14,984	5,455

Table 2.--Number of 5.25-foot bolts per cord for various age-site-density schedules

Age	Site index	Trees per acre						
		200	300	400	500	600	700	800
		Number						
10	50	258	344	405	463			
	60	165	209	240	248			
	70	126	154	169	179	186	184	187
	80	102	125	138	145	151	151	150
15	50	105	129	146	156	164	167	171
	60	85	101	114	123	128	133	136
	70	68	85	95	103	108	112	114
	80	64	75	83	90	94	98	101
20	50	82	99	110	120	126	132	
	60	68	81	90	98	104	107	
	70	59	70	78	84	89	93	
	80	54	62	69	74	79	82	
25	50	72	86	96	104	111		
	60	61	72	80	86	92		
	70	54	62	69	75	80		
	80	49	56	62	67	71		
30	50	67	79	89	97			
	60	57	66	74	80			
	70	50	59	65	70			
	80	46	53	58	63			

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E. C. Franklin

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Survey of Mutant Forms and Inbreeding Depression in Species of the Family Pinaceae[1]

by

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INTRODUCTION

Inbreeding experiments in Pinaceae date back at least to the early part of this century (Sylven 1910). Unfortunately, a large amount of information on mutants and inbreeding depression in Pinaceae is buried in reports which deal primarily with other topics. This fact has prompted me to compile a list of world literature on inbreeding in this family. It is not intended to be an intensive review of all the results, theories, and conclusions to be found in the reports listed. Rather, the aim was to bring into one report a list of mutant forms, a tabulation of effects of inbreeding depression, and a bibliography of reports pertaining to these subjects. This report is intended to serve as a handy reference source for quickly reaching the literature by author and species. I hasten to admit that, in an attempt such as this, omissions and inaccuracies may occur, but I believe that the generalizations reached herein are the best obtainable at this time.

MUTANT FORMS

Self-pollinations have usually been done as adjuncts to other, larger breeding studies, and the resulting progenies have received only limited attention. Descriptions of mutant forms have been sketchy; and records of segregation patterns have seldom been made.

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[1] Based on a comprehensive review of literature for a dissertation presented to the Graduate School, North Carolina State University at Raleigh, in partial fulfillment of requirements for the degree of Doctor of Philosophy. Funds and assistance for this research were provided by the North Carolina State University Cooperative Tree Improvement Program, the National Institute of Health Grant G. M. 11546, and the Southeastern Forest Experiment Station. The trees were located on lands owned by Albemarle Paper Manufacturing Company, Roanoke Rapids, North Carolina.

Classification of the myriad types of chlorophyll-deficient mutants is a difficult job. Some authors, notably Eiche (1955) and Snyder et al. (1966), have adapted for pines the classification system used by Gustafsson (1940) for chlorophyll-deficient mutants in barley. Other authors have simply described the mutant seedlings. In either case, it is risky to compare mutant types on the basis of published descriptions alone. For example, the term "albino" is appropriately applied only to forms lacking all color in the cotyledons, but occasionally the term is used to refer to any chlorophyll-deficient seedling. Another confusing factor is that some of the mutant forms are very labile when exposed to varying light, temperature, or nutrient levels (Eiche 1955; Snyder et al. 1966). Most of the reported mutants are chlorophyll-deficient abnormalities, probably because these are most easily seen, although it may be that pigmentation is more subject to alteration than are other morphological features.

The variety of phenodeviants produced by self-pollination among species of the genus Pinus has been very large, even though a relatively small number of species has been observed. Descriptions of many mutant phenotypes in Pinus have been published, some with and some without accompanying segregation data (table 1). Reports of mutant forms in the genus Picea have involved only three species (table 2).

INBREEDING DEPRESSION IN METRICAL TRAITS

Deleterious effects of inbreeding, usually of selfing, have been observed in every genus of the family Pinaceae which has been studied. The literature contains reports on one or more species in each of four genera. Overall similarity of response to self-fertilization among genera is striking, especially when the large differences in experimental conditions over half a century in all parts of the world are considered.

To facilitate comparisons between results of many different experiments, it was necessary to bring metrical results into a common form which was independent of experimental methods and conditions, as far as possible. This was accomplished by dividing performance values (usually family means) resulting from self-pollination by performance values resulting from check-pollinations, thus deriving a ratio of self- to check-performance for each trait. This ratio does not reflect differences on an absolute scale, but it does allow comparisons between experiments, species, and genera on a relative scale. A summary of these results by genera permits tentative comparisons at the generic level (table 3). Data from individual experiments are listed by authors and species, with specific summaries when warranted (tables 4 through 11). Caution must be exercised in interpreting these data, especially for certain individual experiments and species averages, because of the paucity of experimental results.

(Text continues on page 13)

Table 1.--Abnormal phenotypes observed in inbred and open-pollinated families of Pinus species

Species	Author and date	Brief description of abnormality	Number of parent trees	Segregation information[1]
P. banksiana Lamb.	Fowler 1965c, 1965d	Small, chlorotic, short cotyledons (usually 4). Lethal at 3 to 4 weeks	1	3:1
		Pale-yellow cotyledons, developing normal pigments at about 6 weeks	1	10.3:1
		White cotyledons, developing normal pigment at about 6 weeks	1	15:1
		Inverted germination--cotyledons appear first	2	--
	Rudolph 1966	Combined all types of cotyledonary chlorophyll deficiencies from control and X-ray treated families	27	1:1, 2:1, 3:1, 7:1, 15:1
		Cotyledons normal-green; primary foliage yellow	3	3:1, 15:1, 63:1
		Cotyledons pale-yellow; primary foliage green	4	9:1, 72:1, 3:1
		Thick, twisted, light-green hypocotyl; twisted, thick cotyledons	2	3:1
		Bright yellow-green hypocotyl	1	3:1
		Primary foliage short, thick, bluish-green; epicotyl dwarf	1	3:1
P. elliottii Engelm.	Kraus and Squillace 1964	Yellow oleoresin	1	Homozygous recessive
		Virescent; yellow-green foliage turning green toward end of first season	3	Homozygous recessive
	Snyder et al. 1966	Albino (lethal)	1	Open-pollinated
		Xantha-yellow cotyledons (lethal)	25	3:1
		Xantha-G yellow-green cotyledons	15	3:1
		Viridis light-green cotyledons	9	3:1
P. jeffreyi Grev. & Balf.	Johnson 1948	Albino (lethal)	1	3:1
P. monticola Dougl.	Bingham and Squillace 1955	Albino (lethal)	1	--
	Barnes 1964	Albino (lethal)	1	3:1
P. nigra var. austriaca Arnold	Johnson 1948	Albino (lethal)	1	3:1
		Greenish-yellow primary needles	1	--
P. peuce Griseb.	Johnson 1948	Albino (lethal)	1	--
P. radiata D. Don	Pawsey 1964	Dwarfs with short, distorted needles	3	--
		Needles partially fused within a fascicle	1	16 percent abnormal types
	Bannister 1965	Bright-green, fused cotyledons (lethal, but some lived 4 years)	3	3:1
		Albino (lethal), some yellow or pale-green pigments noted	1	Open-pollinated
		Repeated dichotomies in the shoots, seen at 2 years and older	--	Open-pollinated
		Tips of cotyledons blood-red as seedcoat is shed	--	Open-pollinated
	Bannister (personal communication)	Seedling primary needles golden in color	1	3:1
		Bluish foliage; shortened, recurved primary leaves; stunted	1	--
		Golden-yellow cotyledons and primary needles (lethal)	2	3:1
		Pale, almost white cotyledons; green primary needles	4	Open-pollinated
		Green cotyledons; pale, almost white primary needles	1	Open-pollinated

Table 1.--Abnormal phenotypes observed in inbred and open-pollinated families of Pinus species (continued)

Species	Author and date	Brief description of abnormality	Number of parent trees	Segregation information[1]
P. resinosa Ait.	Fowler 1962, 1964b	Light yellow-green cotyledons and pink hypocotyls (lethal)	1	3:1
	Fowler 1965b	Chlorotic at germination, becoming normal in about 1 month	1	Open-pollinated
P. strobus L.	Johnson 1945	Emerging needles white to cream, changing through the season to yellowish-white or yellowish-green, and light-green in the fall	1	3:1
	Fowler 1965c	Predisposition to forking because of lack of apical dominance	1	5.5:1
		Twisted needles from the same trees as above	1	7.3:1
P. sylvestris L.	Degelius 1943	Emerging needles yellowish-white changing to light-green in late season	--	One open-pollinated tree observed
	Eiche 1955	Albino (lethal)	>400	Open-pollinated
		Yellow cotyledons (lethal)	>400	Open-pollinated
		Greenish-yellow cotyledons	>400	Open-pollinated
		Light-green to yellowish-green cotyledons	>400	Open-pollinated
		Primary foliage white and short; secondary foliage not produced	>400	Open-pollinated
		Primary foliage yellow and short; secondary foliage yellow if produced	>400	Open-pollinated
		Primary foliage whitish-green or green in the first pairs; secondary foliage contains white and shades of green and yellow	>400	Open-pollinated
		Primary foliage green, grading to yellow in upper epicotyl; secondary foliage yellow	>400	Open-pollinated
		Primary and secondary foliage light-green in varying shades	>400	Open-pollinated
P. thunbergii Parl.	Katsuta 1966b	Dwarf seedlings	--	--

[1] Self-pollination was used in all cases unless open-pollination is specified.

Table 2.--Abnormal phenotypes observed in inbred and open-pollinated families of *Picea* species

Species	Author and date	Brief description of abnormality	Number of parent trees	Segregation information[1]
P. abies (L.) Karst.	Langner 1953, 1954	Yellow or white needles ("Aurea-Forms")	1	1:2:1
	Illies 1958	Dwarf seedlings, some of which were mixoploids	8	Open-pollinated
	Langner 1959	Yellow secondary foliage	--	--
	Andersson 1965	Light-green, yellow-green, and albino seedlings	1	Open-pollinated
		Other chlorophyll defects	3	Open-pollinated
P. omorika (Pančić) Purkyne	Langner 1959	Yellow secondary foliage	--	--
P. pungens Engelm.	Cram 1960	Yellow seedlings	1	3:1
		Albino	1	Open-pollinated
	Cram 1962	Albino	1	3:1

[1] Self-pollination was used in all cases unless open-pollination is specified.

Table 3.--Effects of one generation of selfing on seed and seedling traits in four genera, expressed as ratios of performance after self-pollination divided by performance after check-pollination[1]

Genera	Cone yield	Total seed yield	Filled seed yield	Empty seed yield	Filled seed germination	Average seed weight	Germination rate	Height	Diameter	Mortality
Pinus	1.07	0.99	0.66	2.39	0.89	0.98	0.89	0.90	0.96	1.31
Picea	[2] .65	1.08	.40	1.67	.83	[2] .91	[2]1.02	.91	[2] .47	1.82
Larix	[3]1.05	1.05	.15	1.44	.81	1.01	--	.73	—	[3]1.13
Pseudotsuga[4]	.99	.82	.26	1.32	.89	.71	--	.68	.83	1.61
Mean	1.05	1.00	.54	2.13	.88	.97	.89	.88	.85	1.36

[1] All means were weighted according to number of families of each species used to estimate the generic mean.

[2] Based on *Picea abies* only (see table 7).

[3] Based on *Larix decidua* only (see tables 8 and 9).

[4] Represented by *Pseudotsuga menziesii* (Mirb.) Franco only.

Table 4.--Effects of inbreeding on cone and seed traits in the genus Pinus, expressed as ratios of performance after self-pollination divided by performance after check-pollination

Species, numbers* and types of families	Author and date	Cone yield	Total seed yield	Filled seed yield	Empty seed yield	Filled seed germinated	Mean seed weight	Type of check-pollination
P. banksiana Lamb.								
(5*) S_1	Fowler 1965c	1.19	1.21	0.42	8.58	0.98	0.93	Control cross
P. densiflora Sieb. & Zucc.								
(2*) S_1	Katsuta 1964	.63 (5*)	1.84 (3*)	.42	2.65	.77	1.07	Wind
(4*) S_1[1]	Katsuta 1966a	--	1.07	.42	2.65	--	--	Wind
Species average of S_1		.63	1.40	.42	2.65	.77	1.07	
P. echinata Mill.								
(1*) S_1	Snyder and Squillace 1966	.93	0	--	--	--	--	Control cross
P. elliottii Engelm.								
(7*) S_1	Squillace and Kraus 1963a	--	--	--	--	.22	--	Control cross among original parents
(7*) BC_1		--	--	--	--	.44	--	Control cross among original parents
(4*) FS x FS		--	--	--	--	.61	--	Control cross among original parents
(4*) HS x HS		--	--	--	--	.93	--	Control cross among original parents
(7*) S_1	Kraus and Squillace 1964	1.04 (3*)	.52	.22	--	.47	.90 (3*)	Control cross
(16*) S_1	Snyder and Squillace 1966	.78	--	.16	--	--	--	Control cross
(35*) S_1	Snyder 1968	--	--	.15	--	.71	1.00 (11*)	Wind
Species average of S_1		.82	.52	.18	--	.34	.90	
P. griffithii McClel.								
(--) S_1	Wright 1953	4.62	1.19	1.03	.98	--	--	Control cross
P. jeffreyi Grev. & Balf.								
(1*) S_1	Righter 1945	--	--	--	--	.91	1.01	Control[2] cross
P. monticola Dougl.								
(28*) S_1	Bingham and Squillace 1955	1.00	.98	.53	2.76	.90	1.07 (16*)	Control cross
(4*) S_1	Barnes et al. 1962	.92	1.18	.75	10.93	.69	1.00	Control cross
Species average of S_1		.99	1.00	.56	3.78	.87	1.06	
P. palustris Mill.								
(5*) S_1	Snyder and Squillace 1966	.97	—	.37	--	--	--	Control cross
P. parviflora Sieb. & Zucc.								
(--) S_1	Wright 1953	.25	.57	2.78	.82	--	--	Control cross

Table 4.--Effects of inbreeding on cone and seed traits in the genus *Pinus*, expressed as ratios of performance after self-pollination divided by performance after check-pollination (continued)

Species, numbers* and types of families	Author and date	Cone yield	Total seed yield	Filled seed yield	Empty seed yield	Filled seed germi-nated	Mean seed weight	Type of check-pollination
P. radiata D. Don								
(27*) S_1	Pawsey 1964	1.02	0.74 (12*)	--	1.04	0.77 (18*)	0.73 (21*)	Control cross and wind
(11*) S_2		1.09	--	--	--	.79 (6*)	.65 (5*)	Control cross and wind
(11*) S_1 x parent		--	--	0.29	--	--	--	Control cross and wind
P. resinosa Ait.								
(1*) S_1	Johnson 1945	--	.69	--	--	--	--	Control cross
(9*) S_1	Fowler 1962	1.06	1.08	1.04	.98	1.01	.98	Pollen mix
(58*) S_1	Fowler 1965a	1.15	1.08	1.02	1.12	1.09	1.07	Control cross
Species average of S_1		1.14	1.07	1.02	1.10	1.08	1.06	
P. strobus L.								
(1*) S_1	Johnson 1945	--	.93	.90	1.11	--	--	Control cross
(--) S_1	Wright 1953	.41	4.12	.61	1.27	-	--	Control cross
(1*) S_1	Fowler 1965c	--	1.47	.85	1.37	1.17	--	Control cross
Species average of S_1		.41	2.17	79	1.25	1.17	-	
P. sylvestris L.								
(1*) S_1	Johnson 1945	--	.44	.23	1.61	--	--	Control cross
(8*) S_1	Forshell 1953	--	--	.38	--	.69 (13*)	1.00	Control cross and wind
(11*) S_1	Ehrenberg and Simak 1956	1.61 (10*)	.99	.28	5.85	--	--	Wind
Species average of S_1		1.61	94	.32	5.50	.69	1.00	
P. tabulaeformis Carr.								
(--) S_1	Wright 1953	.21	0	--	--	--	--	Control cross
P. taeda L.								
(7*) S_1	Snyder and Squillace 1966	1.24	--	.20	--	--	--	Control cross
P. thunbergii Parl.								
(4*) S_1	Katsuta 1964	.88	.82	.71	3.94	.77	1.10	Wind
(28*) S_1[1]	Katsuta 1966a	--	.85	.77	2.67	--	-	Wind
(4*) S_2		.16	.30	.30	6.12	--	--	Wind
(10*) S_1 x S_1[3]		.23	.44	.36	4.28	--	--	Wind
(9*) S_1 x parent		.19	.52	.50	2.61	--	--	Wind
Species average of S_1		.88	.85	.77	2.67	.77	1.10	

---

[1] Includes 1964 data.

[2] *P. jeffreyi* x (*P. jeffreyi* x *P. coulteri* D. Don) were used as control.

[3] Siblings of the same selfed family.

*Species averages were weighted according to the numbers of families used for each estimate. If the number of families for a particular ratio is different from that shown in parentheses in the left column, the number is shown in parentheses under the particular ratio.

Table 5.--Effects of inbreeding on progeny performance in the genus *Pinus*, expressed as ratios of performance after self-pollination divided by performance after check-pollination

Species, numbers* and types of families	Author and date	Speed of germination	Height[1]	Diameter[1]	Mortality[1]	Type of check-pollination
P. banksiana Lamb.						
(5*) S_1	Fowler 1965c	--	0.95 (1 yr.)	--	1.10 (1 yr.)	Control cross
P. elliottii Engelm.						
(1*) S_1	Mergen 1954	--	.79 (5 yr.)	--	--	Control cross
(7*) S_1	Squillace and Kraus 1963b	0.34	.70 (1 yr.)	--	--	Control cross among original parents
(7*) BC_1		.71	.88 (1 yr.)	--	--	Control cross among original parents
(4*) FS x FS		.94	.98 (1 yr.)	--	--	Control cross among original parents
(4*) HS x HS		.69	.93 (1 yr.)	--	--	Control cross among original parents
(3*) S_1	Kraus and Squillace 1964	.80	.70 (1 yr.)	--	--	Control cross
(35*) S_1	Snyder 1968	--	.80 (1 yr.) (12*)	--	4.00 (1 yr.)	Wind
Species average of S_1		.48	.78	--	4.00	
P. jeffreyi Grev. & Balf.						
(1*) S_1	Righter 1945	1.05	.68 (1 yr.)	--	.82 (1 yr.)	Control[2] cross
		--	.62 (2 yr.)	--	-	Control[2] cross
		--	.54 (3 yr.)	--	--	Control[2] cross
Species average of S_1		1.05	.61	--	.82	
P. monticola Dougl.						
(16*) S_1	Bingham and Squillace 1955	--	.89 (1 yr.)	--	--	Control cross
		--	.79 (2 yr.) (8*)	--	--	Control cross
		--	.79 (3 yr.) (6*)	--	--	Control cross
(4*) S_1	Barnes et al. 1962	.80	--	--	1.29 (1 yr.)	Control cross
(5*) S_1	Barnes 1964	--	.71 (1 yr.)	--	1.64 (9-12 yr.)	Control cross
		--	.31 (9-12 yr.)	--	--	Control cross
Species average of S_1		.80	.76	--	1.48	
P. radiata D. Don						
(2*) S_1	Pawsey 1964	--	.98 (1 yr.)	1.00 (1 yr.)	1.48 (1 yr.) (7*)	Control cross and wind
		--	1.02 (4 yr.)	.92 (4 yr.)	—	Control cross and wind
		--	.90 (8 yr.) (1*)	.82 (8 yr.) (1*)	.72 (7 yr.) (2*)	Control cross and wind
(6*) S_2		--	--	--	1.46 (1 yr.)	Control cross and wind
(1*) S_1 x parent		--	.84 (4 yr.)	--	2.04 (1 yr.) (11*)	Control cross and wind
		--	.87 (6 yr.)	--	--	Control cross and wind
Species average of S_1		--	.98	.93	1.31	

Table 5.--Effects of inbreeding on progeny performance in the genus Pinus, expressed as ratios of performance after self-pollination divided by performance after check-pollination (continued)

Species, numbers* and types of families	Author and date	Speed of germination	Height[1]	Diameter[1]	Mortality[1]	Type of check-pollination
P. resinosa Ait.						
(9*) S_1	Fowler 1962	1.01	[3]0.94 (1 yr.)	0.98 (1 yr.)	--	Pollen mix
(58*) S_1	Fowler 1965a	.95	[3]1.02 (1 yr.)	--	--	Pollen mix
Species average of S_1		.96	1.01	.98	--	
P. strobus L.						
(1*) S_1	Johnson 1945	--	.78 (4 yr.)	--	-	Control cross
(1*) S_1	Fowler 1965c	--	.86 (1 yr.)	--	--	Control cross
Species average of S_1		--	.82	--	--	
P. sylvestris L.						
(1*) S_1	Johnson 1945	--	.63 (4 yr.)	--	--	Control cross
P. thunbergii Parl.						
(3*) S_1	Katsuta 1964	--	.82 (4 yr.)	--	-	Wind
(1*) S_1	Katsuta 1966b	--	.47 (7 yr.)	--	-	Wind
Species average of S_1		--	.73	--	--	

[1] Numbers to the right in parentheses indicate age at time of measurement.

[2] P. jeffreyi x (P. jeffreyi x P. coulteri D. Don) used as control.

[3] Hypocotyl height.

*Species averages were weighted according to the number of families used for each estimate. If the number of families for a particular ratio is different from that shown in parentheses in the left column, the number is shown in parentheses under the particular ratio.

Table 6.--Effects of inbreeding on seed traits in the genus Picea, expressed as ratios of performance after self-pollination divided by performance after check-pollination

Species, numbers* and types of families	Author and date	Cone yield	Total seed yield	Filled seed yield	Empty seed yield	Filled seed germinated	Mean seed weight	Type of check-pollination
P. abies (L.) Karst.								
(4*) S_1	Sylven 1910; Langlet 1940	--	--	--	--	0.60	0.96	Wind
(3*) S_1	Andersson 1947	--	1.22 (4*)	1.02	1.04 (4*)	.09	.80	Control cross
(19*) S_1	Wright 1953, 1955	--	--	.03	--	-	--	Wind and control cross
(2*) S_1	Langner 1959	--	1.04	.14 (1*)	1.30	--	--	Control cross
(5*) S_1	Kleahn and Wheeler 1961	--	--	.05	1.75	0	.72	Control cross
(6*) S_1	Dieckert 1964a	0.65	.93	.77	1.23	.31	-	Control cross
(1*) S_1	Dieckert 1964b	--	.64	.32	1.91	--	1.04	Control cross
(2*) S_1	Andersson 1965	--	1.04	.04	3.05	--	--	Wind
(4*) S_2		--	.80	.03	2.32	--	-	Wind
Species average of S_1		.65	1.02	.24	1.54	.25	.84	

Table 6.--Effects of inbreeding on seed traits in the genus *Picea*, expressed as ratios of performance after self-pollination divided by performance after check-pollination (continued)

Species, numbers* and types of families	Author and date	Cone yield	Total seed yield	Filled seed yield	Empty seed yield	Filled seed germinated	Mean seed weight	Type of check-pollination
P. asperata Mast.								
(6*) S_1	Wright 1955	--	--	0.55	--	--	--	Control cross
P. glauca (Moench) Voss								
(21*) S_1	Wright 1953, 1955	--	--	.34	1.58	--	--	Wind
(1*) S_1	Langner 1959	--	1.01	--	1.04	--	--	Control cross
(4*) S_1	Kleahn and Wheeler 1961	--	--	0	2.32	--	0.53	Control cross
(20*) S_1	Mergen et al. 1965	--	1.15	.22	2.18	--	--	Wind
Species average of S_1		--	1.14	.26	1.89	--	.53	
P. jezoensis (Sieb. & Zucc.) Carr.								
(1*) S_1	Langner 1959	--	.62	.43	6.16	--	--	Control cross
P. montigena Mast.								
(2*) S_1	Wright 1955	--	--	0	--	--	--	Control cross
P. omorika (Pancić) Purkyne								
(8*) S_1	Wright 1955	--	--	1.02	--	--	--	Control cross
(12*) S_1	Langner 1959	--	1.08	1.21	.96	1.07	--	Control cross
Species average of S_1		--	1.08	1.13	.96	1.07	--	
P. pungens Engelm.								
(9*) S_1	Cram 1964	--	--	.16	--	--	--	Wind
(29*) S_1	Cram 1967	--	--	.28	--	--	--	Wind
Species average of S_1		--	--	.25	--	--	--	
P. sitchensis (Bong.) Carr.								
(2*) S_1	Langner 1959	--	.90	.01 (1*)	1.34	--	--	Control cross

*Species averages were weighted according to the number of families used for each estimate. If the number of families for a particular ratio is different from that shown in parentheses in the left column, the number is shown in parentheses under the particular ratio.

Table 7.--Effects of inbreeding on progeny performance in the genus *Picea*, expressed as ratios of performance after self-pollination divided by performance after check-pollination

Species, numbers* and types of families	Author and date	Speed of germination	Height[1]	Diameter[1]	Mortality[1]	Type of check-pollination
P. abies (L.) Karst.						
(4*) S_1	Langlet 1940	—	0.48 (27 yr.)	0.47 (27 yr.)	2.52 (1 yr.)	Wind
(1*) S_1	Langner 1959	--	.93 (2 yr.)	--	--	Control cross
(6*) S_1	Dieckert 1964a	--	--	--	1.29 (4 yr.)	Control cross
(2*) S_1	Andersson 1965	1.02	--	--	--	Wind
(3*) S_2		1.04	--	--	--	Wind from parents of S_1
Species average of S_1		1.02	.48	.47	1.82	
P. glauca (Moench) Voss						
(20*) S_1	Mergen et al. 1965	--	.91 (6 wk.)	--	--	Wind
		--	1.02 (1 yr.)	--	--	Wind
		--	1.13 (3 yr.) (2*)	--	--	Wind
Species average of S_1		--	.97	--	--	
P. omorika (Pancić) Purkyne						
(12*) S_1	Langner 1959	--	.84 (2 yr.)	--	--	Control cross

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[1] Numbers to the right in parentheses indicate age at the time of measurement.

*Species averages were weighted according to the number of families used for each estimate. If the number of families for a particular ratio is different from that shown in parentheses in the left column, the number is shown in parentheses under the particular ratio.

Table 8.--Effects of inbreeding on seed traits in the genus *Larix*, expressed as ratios of performance after self-pollination divided by performance after check-pollination

Species, numbers* and types of families	Author and date	Cone yield	Total seed yield	Filled seed yield	Empty seed yield	Filled seed germinated	Mean seed weight	Type of check-pollination
L. decidua Mill.		--	--	--	--	--	--	
L. leptolepis Gord.		--	--	--	--	--	--	
L. siberica Ledeb.		--	--	--	--	--	--	
L. leptolepis x *L. decidua*		--	--	--	--	--	--	
(9*) S_1[1]	Nilsson 1959	--	1.10	0.15	1.44	0.76	1.01	Control cross
L. dahurica Turcz.								
(1*) S_1	Piatnitsky 1934	--	1.24	--	--	.87	--	Wind
L. decidua Mill.								
(13*) S_1	Dieckert 1964a	1.05	1.03	--	--	--	--	Control cross
L. europaea D. C.								
(1*) S_1	Piatnitsky 1934	--	--	--	--	.11	--	Wind
L. leptolepis Gord.								
(1*) S_1	Piatnitsky 1934	--	--	--	--	1.57	--	Wind
L. siberica Ledeb.								
(2*) S_1	Piatnitsky 1934	--	.82	--	--	.97	--	Wind

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[1] Averages of three species and one hybrid.

*The number of families used for each estimate is shown in parentheses.

Table 9.--Effects of inbreeding on progeny performance in the genus *Larix*, expressed as ratios of performance after self-pollination divided by performance after check-pollination

Species, numbers* and types of families	Author and date	Height[1]	Mortality[1]	Type of check-pollination
L. decidua Mill.		--	--	
L. leptolepis Gord.		--	--	
L. siberica Ledeb.		--	--	
L. leptolepis x *L. decidua*		--	--	
(6*) S_1[2]	Nilsson 1959	0.59 (2 yr.)	--	Control cross
L. decidua Mill.				
(1*) S_1	Langner 1962	.73 (9 yr.)	--	Control cross
(13*) S_1	Dieckert 1964a	.91 (6 yr.) (4*)	1.13 (4 yr.)	Control cross
L. leptolepis Gord.				
(--) S_2	Langner 1962	.66 (2 yr.)	--	Control cross
(--) FS x FS		.80 (2 yr.)	--	Control cross
(--) HS x HS		.88 (2 yr.)	--	Control cross
(1*) S_1		.85 (7 yr.)	--	Wind
(1*) FS x FS		.71 (7 yr.)	--	Wind
(1*) HS x HS		.81 (7 yr.)	--	Wind

[1] Numbers to the right in parentheses indicate age at time of measurement.

[2] Averages of three species and one hybrid.

*The number of families used for each estimate is shown in parentheses. If the number of families for a particular ratio is different from that shown in parentheses in the left column, the number is shown in parentheses under the particular ratio.

Table 10.--Effects of inbreeding on seed traits in *Pseudotsuga menziesii* (Mirb.) Franco, expressed as ratios of performance after self-pollination divided by performance after check-pollination

Numbers* and types of families	Author and date	Cone yield	Total seed yield	Filled seed yield	Empty seed yield	Filled seed germinated	Mean seed weight	Type of check-pollination
(1*) S_1	Duffield 1950	0.94	0.82	0	---	--	--	Control cross
(8*) S_1	Orr-Ewing[1] 1954, 1957b	1.08 (2*)	.80	.34	1.31	0.89	0.71 (2*)	Control cross
(4*) S_1	Sziklai 1966	.96	.87	.16	1.35	--	--	Control cross
Species average of S_1		.99	.82	.26	1.32	.89	.71	

[1] Data on the same tree were published in both years.

*Species averages were weighted according to the number of families used for each estimate. If the number of families for a particular ratio is different from that shown in parentheses in the left column, the number is shown in parentheses under the particular ratio.

Table 11.--Effects of inbreeding on phenotypic traits of offspring in Pseudotsuga menziesii (Mirb.) Franco, expressed as ratios of performance after self-pollination divided by performance after check-pollination

Numbers* and types of families	Author and date	Height[1]	Diameter[1]	Mortality[1]	Type of check-pollination
(8*) S_1	Orr-Ewing 1954, 1957b	0.73 (1 yr.)	0.83 (1 yr.) (2*)	1.61 (1 yr.) (5*)	Control cross
		.68 (2 yr.)	--	--	Control cross
		.70 (3 yr.) (2*)	--	--	Control cross
		.44 (4 yr.) (2*)	--	--	Control cross
(2*) S_1	Orr-Ewing 1965	.50 (6 yr.)	--	--	Control cross
		.77 (4 yr.) (6*)	--	--	Control cross
(6*) S_2		.75 (4 mo.)	--	.79	Control cross between S_1 families
(2*) S_1 x S_1[2]		1.05 (4 mo.)	--	.95	Control cross between S_1 families
(12*) S_1 x parent		.94 (4 mo.)	--	.87	Control cross between S_1 families
Species average of S_1		.68	.83	1.61	

[1] Numbers to the right in parentheses indicate age at the time of measurement.

[2] Siblings of the same selfed family.

*Species averages were weighted according to the number of families used for each estimate. If the number of families for a particular ratio is different from that shown in parentheses in the left column, the number is shown in parentheses under the particular ratio.

GENERIC COMPARISONS

Neither cone yield (cones matured per conelets pollinated) nor total seed yield (filled plus empty) in Pinaceae were affected by selfing. Picea had an unusually low cone-yield ratio, but this ratio was based on only six families in one experiment with Picea abies (L.) Karst. (table 6, Dieckert 1964a). The low total seed-yield ratio for Pseudotsuga, represented only by P. menziesii (Mirb.) Franco, was consistently low for three different experiments involving a total of 13 families (table 10). This consistency gave weight to the conclusion that selfing produced a significant depressing effect on total seed yield in this species.

In Pinaceae, filled seed yields from self-pollination were only half as large as those from cross- and wind-pollination, but there was wide variation among the genera in this trait. Pinus showed the least reduction, Larix the most, while Picea and Pseudotsuga had intermediate ratios. Yields of empty seed were more than doubled by self-pollination as compared to those from cross- and wind-pollination. Pinus yielded almost 2.4 times as many empty seeds after selfing as after crossing. Ratios for the other genera ranged from 1.32 to 1.67.

Reduced yield of filled seed has been one of the most consistent results of inbreeding depression. Many researchers have attempted to discover the cause or causes of this reduction. As early as 1932, A. Dengler, reporting on Pinus sylvestris L., concluded "... that in the case of self-pollination, by [the time of] fertilization of the sexual cells or the beginning of embryo development, frequently some retardation appeared; thus the development of full seeds was retarded or prevented." [2] Retarded growth of the pollen tube because of lack of inherent vigor (Barnes et al. 1962) and reduced fertilization because of represser substances (Forshell 1953) have both been suggested as explanations of the low filled seed yields that result from selfing. However, cytological studies in Picea glauca (Moench) Voss (Mergen et al. 1965), Pinus peuce Griseb., Pinus sylvestris, Pinus cembra L., Pinus contorta var. latifolia Engelm. (Hagman and Mikkola 1963; Hagman 1964), Pinus sylvestris (Forshell 1953), and Pseudotsuga menziesii (Orr-Ewing 1957a) have shown that neither pollen germination, growth of the pollen tube, nor fertilization capability were reduced as a result of self-pollination. There was general agreement among these and other authors (Ehrenberg et al. 1955; Sarvas 1962; Kraus and Squillace 1964; Fowler 1964b and 1965b) that embryo abortion between fertilization and germination accounts for reduced yields of filled seed after selfing.

In some instances, embryonic abortion results from particulately inherited lethal factors (Sorensen 1967); in other instances, it results from the accumulative action of genes with small individual effects. Accumulative effects may be of special importance in the case of polyembryony, in which embryo competition results in strong selection pressure prior to germination. Fowler (1964b) illustrated the effect of embryo competition through the use of a series of pollinations with varying proportions of self and cross pollens. Barnes et al. (1962) and Kraus and Squillace (1964) also used pollen mixes to compare the results of selfing and crossing under conditions of embryonic competition. Although their results were not conclusive, they suggested that embryos resulting from cross-fertilization will usually prevail when in direct competition with those from self-fertilization.

Self-fertilized seed showed a reduction in percentage of germination as compared to cross- and wind-pollinated seed. Ratios were consistent among the four genera, ranging from 0.81 to 0.89 with a mean of 0.88.

Weight of filled seed was affected relatively little by selfing. The ratio of self- to check-performance for Pinaceae was 0.97. Pseudotsuga was the only genus which showed an appreciable reduction in seed weight as a result of selfing.

The effects of self-fertilization on the rate of germination have been measured only in Pinus and Picea. A slight reduction in rate of germination was indicated for Pinus, but no effects were found for Picea.

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[2] Translated from German by E. C. Franklin, as quoted by Forshell (1953), p. 21.

Reduced vigor as a result of self-pollination as compared to cross- and wind-pollination was evident from both height and diameter measurements. Performance ratios were 0.88 for height measurements and 0.85 for diameter measurements. Mortality over all ages was 1.3 times as frequent among self-pollinated seedlings as it was among control- and wind-pollinated seedlings. The ratios for the four genera were fairly consistent, ranging from 1.13 to 1.82.

Some reports on the deleterious effects of selfing included no data, but they were consistent with the quantitative reports already cited. Self-pollination in *Pinus sylvestris* and *Pinus mugo* Turra yielded progeny with low vigor, poor stem form, and stunted growth (Scamoni 1950). *Pseudotsuga glauca* Mayr, and *Picea canadensis* (Mill.) B. S. P. as exotics in Lithuanian S. S. R. were self-sterile (Navasajtis 1966). Selfed seed of *Larix leptolepis* Gord. germinated more slowly than crossed seed, and selfed seed of *Larix europaea* D. C. failed to germinate at all (Gothe 1952).

SPECIFIC COMPARISONS

Within genera, the response of species to selfing was difficult to assess because of the large amount of sampling error associated with most species averages. However, among the species which have been most thoroughly studied, two were particularly interesting. On the basis of seed traits, neither *Pinus resinosa* Ait. nor *Picea omorika* (Pancić) Purkyne showed any signs of inbreeding depression (tables 4 and 6), although seedlings resulting from selfing of *Picea omorika* were retarded in height growth. This general lack of inbreeding depression was in sharp contrast to responses of other members of *Pinus* and *Picea*.

Fowler (1964a) reported that *Pinus resinosa* was found to be relatively free of inbreeding depression because it had undergone much natural inbreeding in the past. He hypothesized that the high degree of inbreeding was caused by drastic reductions in the size of the breeding population during the course of natural reproduction, usually after major stand disturbances such as fire. Presumably, deleterious factors which were recessive became homozygous and were eliminated by natural selection under these conditions. Correspondingly, *Picea omorika* dates back to the tertiary period; it or its ancestors were once widespread, but now it has a relatively limited distribution (Langner 1959). Both Fowler and Langner suggested that the apparent lack of inbreeding depression was a result of the influence of the breeding structure of these two species on the genetic structure of their gene pools during evolutionary development.

The reports cited in this review can be useful as aids in understanding the existing genetic structure of species, the breeding structure of stands, the evolutionary development of species, and the effects of inbreeding that can be expected in applied breeding programs for tree improvement.

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DA Forest Service Research Paper SE-62 June 1970

Early Development of Sweetgum Root Sprouts in Coastal South Carolina

by

Donal D. Hook, Paul P. Kormanik, and Claud L. Brown

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U.S. Department of Agriculture-Forest Service
Southeastern Forest Experiment Station
Asheville, North Carolina

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Donal D. Hook, Paul P. Kormanik, and Claud L. Brown

Sweetgum (Liquidambar styraciflua L.) root sprouts primarily originate from adventitious suppressed root buds and may be released by cutting the parent tree, by minor disturbances within the stand, or in some cases by unknown causes in undisturbed stands.[1] In the southern Piedmont of Georgia sweetgum root sprouts, whether they occur on the roots of living or cut trees, characteristically do not form their own root systems but remain entirely dependent upon the parent root system for support, nutrients, and water absorption. These root sprouts are further characterized by little or no diameter growth of the parent root proximal to their point of origin, but rapid growth of the root just beneath the upright sprout and for some distance distal to it.

Sprouting is prolific--20 to 50 sprouts per parent tree on most sites. Height and diameter growth the first 15 years is comparable to that of planted sweetgum; thus, root sprouts appear to be a potentially important means of regenerating sweetgum. However, lack of secondary root development at the point of sprout origin makes their long term existence questionable in the southern Piedmont. Because of the extensive range and economic importance of sweetgum, it is desirable to know if development of root sprouts in other physiographic areas is similar to that in the southern Piedmont of Georgia.

This paper reports on sweetgum root sprout development in a cutover bottomland hardwood site in coastal South Carolina.

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[1] Kormanik, Paul P., and Brown, Claud L. Root buds and the development of root suckers in sweetgum. Forest Sci. 13: 338-345. 1967.

Hook and Kormanik are, respectively, Plant Physiologist and Silviculturist, Southeastern Forest Experiment Station, Forestry Sciences Laboratory, Athens, Georgia; Brown is Professor of Forestry and Botany, School of Forest Resources, University of Georgia, Athens. This research was conducted while the senior author was stationed at Charleston, South Carolina.

STUDY AREA

In the spring and summer of 1960, an experimental seed tree cut was made in an 85-acre mixed pine-hardwood stand on a small creek bottom and its adjoining terrace on the Santee Experimental Forest, Berkeley County, South Carolina. Soils in the lower areas are Meggett silt and sandy loams and in the more elevated areas are Wagram loamy coarse sand. Abundant rainfall (30+ inches) during the growing season keeps the soils moist to wet most of the time.

Freshly cut stumps of sweetgum, red maple, and ash were sprayed with 2,4,5-T in oil to prevent stump and root sprouting. After logging, residual trees, shrubs, and vines were treated with 2,4,5-T. Larger cull trees were frilled and poisoned, and smaller stems 4.5 feet and taller were basal sprayed. Also in the winter of 1963-64, seed trees were removed and stumps were sprayed with 2,4,5-T in oil. Spraying stumps prevented stump sprouts but not root sprouts. Some stumps were missed by the spray; these developed vigorous root sprouts as well as stump sprouts. Apparently the chemical was not translocated into the roots.

METHODS

In January 1968, the root systems around six sweetgum stumps (cut in 1960) were excavated to determine the nature and extent of root sprouting. Three stumps were located in the creek bottom and three in the adjoining terrace. Approximately half the root system was exposed at each stump; the remainder was left undisturbed for future observations. In addition, the prevalence of root sprouting around other stumps was verified by superficially tracing the roots along the ground to sprouts.

After the root system was exposed and all sprouts identified, 6 to 14 sprouts (about 50 percent) per clump were selected to give a representative sample of range in height and diameter. Height, d.b.h., root diameters (proximal and distal), and length of parent root between sprout and stump were measured for each sprout. Age was determined with increment cores from large sprouts and with disks from smaller sprouts. At each clump of sprouts, two soil samples were collected from the top 4 inches and analyzed for texture and organic matter content. Individual root sprouts of different sizes were felled, and proximal and distal roots were severed 18 to 20 inches from the sprouts. These sections were examined in the laboratory for gross anatomical characteristics and vascular bud traces.

Results and Discussion

Sweetgum root sprouts in the Coastal Plain of South Carolina often develop more extensive secondary root systems than do those in the southern Piedmont of Georgia; otherwise they are similar in origin and early development.

Observations revealed that the sprouts arose from preformed buds in the root and were released when the stand was cut. Unequal diameter growth of the root on the proximal and distal sides of sprouts was identical to that reported for this species in the southern Piedmont.[2] Most sprouts arose on roots within 6 inches of the soil surface. However, the originally felled trees in the Coastal Plain were considerably larger (18 to 30 inches d.b.h.) than trees sampled in the southern Piedmont (8 to 14 inches d.b.h.). As a consequence, sprouts were found on roots much larger (some 12 inches or more in diameter) than those observed in the Piedmont (up to 6 inches in diameter).

The most significant difference between the two areas is that in the Coastal Plains most sprouts developed secondary root systems (fig. 1); this was not observed in the Piedmont.[3]

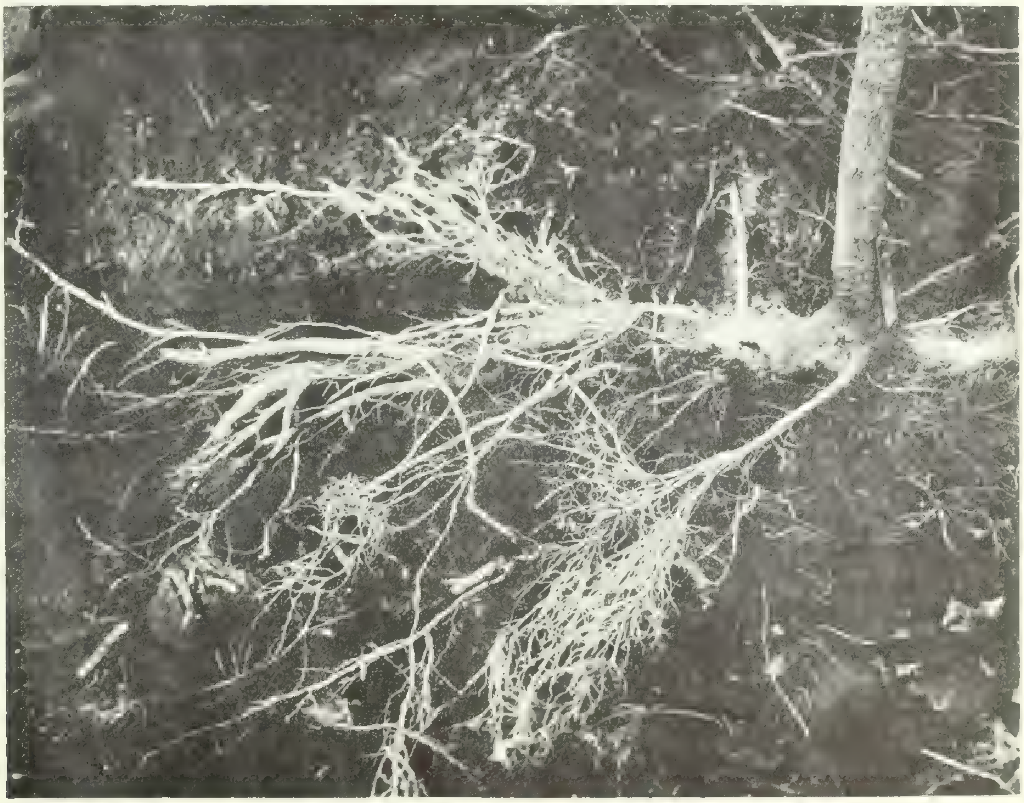

Figure 1.--Secondary root systems appeared to be more heavily branched in the creek bottom.

Secondary root development varied slightly by site within the cut-over area and varied greatly by parent root size. In general, sprouts on smaller parent roots had a much better developed secondary root system than did sprouts on larger parent roots. In the creek bottom, the new root system was highly branched, relatively short, and had some root development on the stem above the parent root (fig. 2). This zonation of roots (development on the stem) was not observed on the terrace site, but roots seemed longer with less branching (fig. 3). In both areas, secondary root development was oriented distally on the parent roots.

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[2] Ibid.

[3] Ibid.

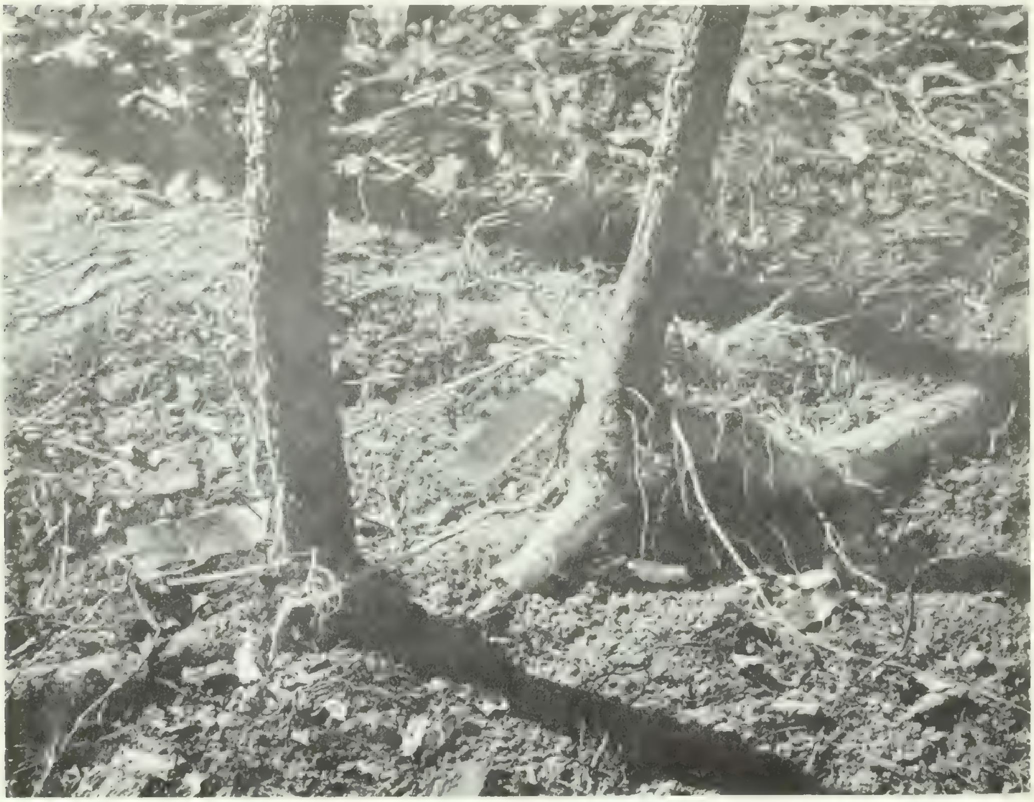

Figure 2.--In the creek bottom, secondary roots frequently originate adventitiously on the stem above the parent root.

We can only speculate why secondary root formation occurs in the Coastal Plain and not in the southern Piedmont of Georgia. In the Piedmont study area, the red clay subsoils are within a few inches of the surface; hence, the shallow surface soil becomes exceedingly dry and hard during frequent periods of short but intense spring and summer droughts. If feeder roots were initiated, their chances of survival in such an environment would be poor. The top 4 inches of a typical Piedmont soil have only about 2 to 4 percent organic matter and are generally high in clay content. On the other hand, the top 4 inches of the Coastal Plain soils are high in both sand and organic matter and seem to be ideally suited as a "rooting medium." The organic matter from the six sample areas averaged 8.3 percent and ranged from 4 to 13 percent in the surface 4 inches, where secondary root development was most

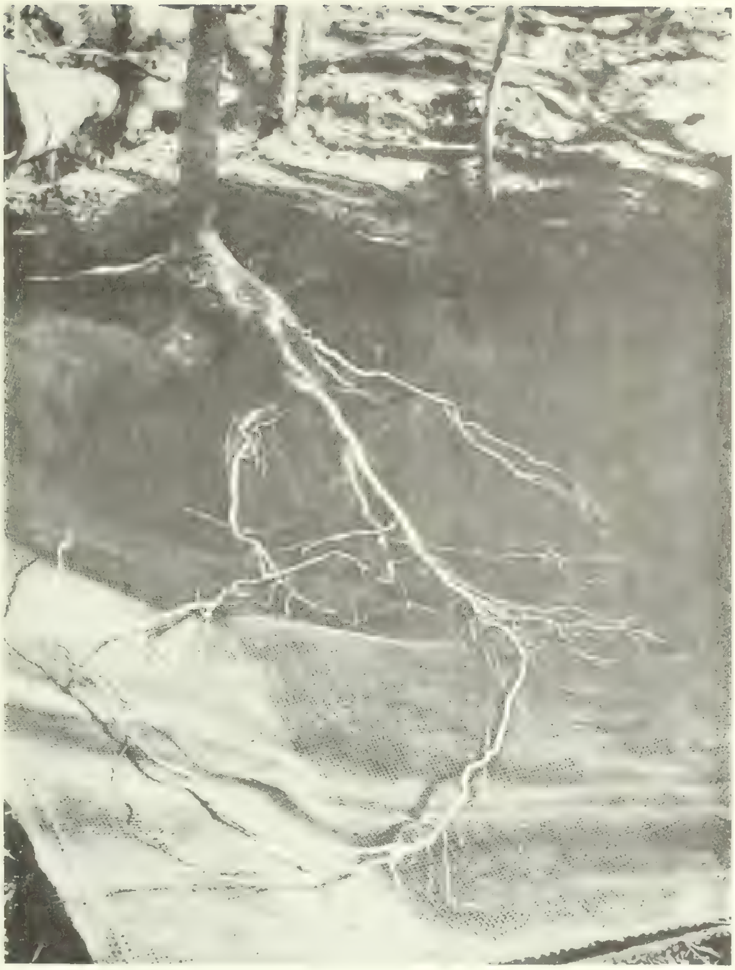

Figure 3.--Longer, less heavily branched secondary root systems were more common on the terrace sites.

prevalent. The high sand content (50 to 70 percent) further enhances root growth. In addition, the abundance of soil moisture during the growing season undoubtedly plays an important role in root development.

Sprout diameters ranged from 0.4 to 4.0 inches and averaged 1.8 inches. Sprout heights ranged from 9.2 to 29.7 feet and averaged 18.4 feet. Variation in sprout size is given in table 1.

The relationship of sprout height to proximal root size and length of root from stump to sprout was analyzed by multiple regression. The final regression equation was

$$Y = 16.2 + 1.5x_1 - 0.12x_2$$

where Y = sprout height (feet)

x_1 = proximal diameter (inches) of parent root

x_2 = length of root from stump to sprout (feet).

This regression accounted for 35.8 percent of the variation in height of sprouts--proximal root size accounted for 27 percent and length of root from parent stump to sprout accounted for 8.8 percent. Hence, position of sprout on the parent root appears to be an important, although secondary, factor in the height growth of the sprout.

Table 1.--Variation in sprout height and diameter by sprout clump at 8 years

Sprout clump	Number[1] of sprouts sampled	Root sprouts			
		Height		Diameter breast height	
		Average	Range	Average	Range
		- - - - Feet - - - -		- - - - Inches - - -	
[2]1	14	17.5	9.2-25.3	1.8	0.6-3.1
2	6	15.9	13.2-18.9	1.6	1.1-2.3
3	9	20.1	10.4-29.7	2.0	0.4-4.0
4	8	19.7	12.7-25.4	2.0	0.9-2.9
5	7	19.5	16.4-24.0	1.6	0.9-2.4
6	6	17.7	15.0-24.4	2.1	1.4-2.6

[1] These include only those sprouts measured on the exposed portion of the parent root system.
[2] On this stump there were four sprouts larger than the largest root sprout.

The rapid height growth of sprouts from large parent roots seems to run contrary to development of secondary root systems; i.e., sprouts on smaller parent roots were shorter but had more advanced secondary root development than did taller sprouts on larger roots. This anomaly may be the result of earlier bud release and a larger quantity of stored carbohydrates in the large roots. Sprouts less than 1 inch d.b.h. were 1 or 2 years younger than the larger sprouts in the same clump. Evidently some buds on smaller roots were not released initially or at least did not grow appreciably the year of the cut or the year after cutting. It seems logical that the large roots would have larger quantities of stored carbohydrates available for the sprout than would small roots; therefore, initially, sprouts on large roots would have an advantage over sprouts on small roots.

It is not clear, however, why or for how long sprouts on larger roots are or will be able to maintain this initial dominance with a limited secondary root system. Nutrient and water absorption must come from the parent root system, and there is evidence that peripheral sprouts (on smaller roots) break their connections with the parent root system faster than do those on the larger roots.

In the laboratory, advanced decay was observed in the specimens from smaller roots, but only incipient decay was apparent in the center portions of the larger roots. It is quite possible that the dominant sprouts will maintain their height and diameter advantage regardless of the fate of the peripheral root system. Only long-term observations will clarify this enigma.

Hook, Donal D., Kormanik, Paul P., and Brown, Claud L.
1970. Early Development of Sweetgum Root Sprouts in Coastal South Carolina. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-62, 6 pp.

Sweetgum sprout development in a mixed pine-hardwood stand on a bottomland site was studied by uncovering a portion of each parent root system 8 years after trees had been cut. Some secondary roots were present on nearly all sprouts, but root development was most pronounced on sprouts that had originated on small-diameter parent roots. Root development was oriented distally from the sprout. Height growth of sprouts was positively correlated with parent root size and negatively correlated with length of root between stump and sprouts. The sprouts on small-diameter parent roots appeared to break their connections to the parent root system faster than those on large-diameter roots. Advanced decay was observed in small connective roots, but only incipient decay was found in large connective roots.

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Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part IV--Pitch Pine
(*Pinus rigida* Mill.)

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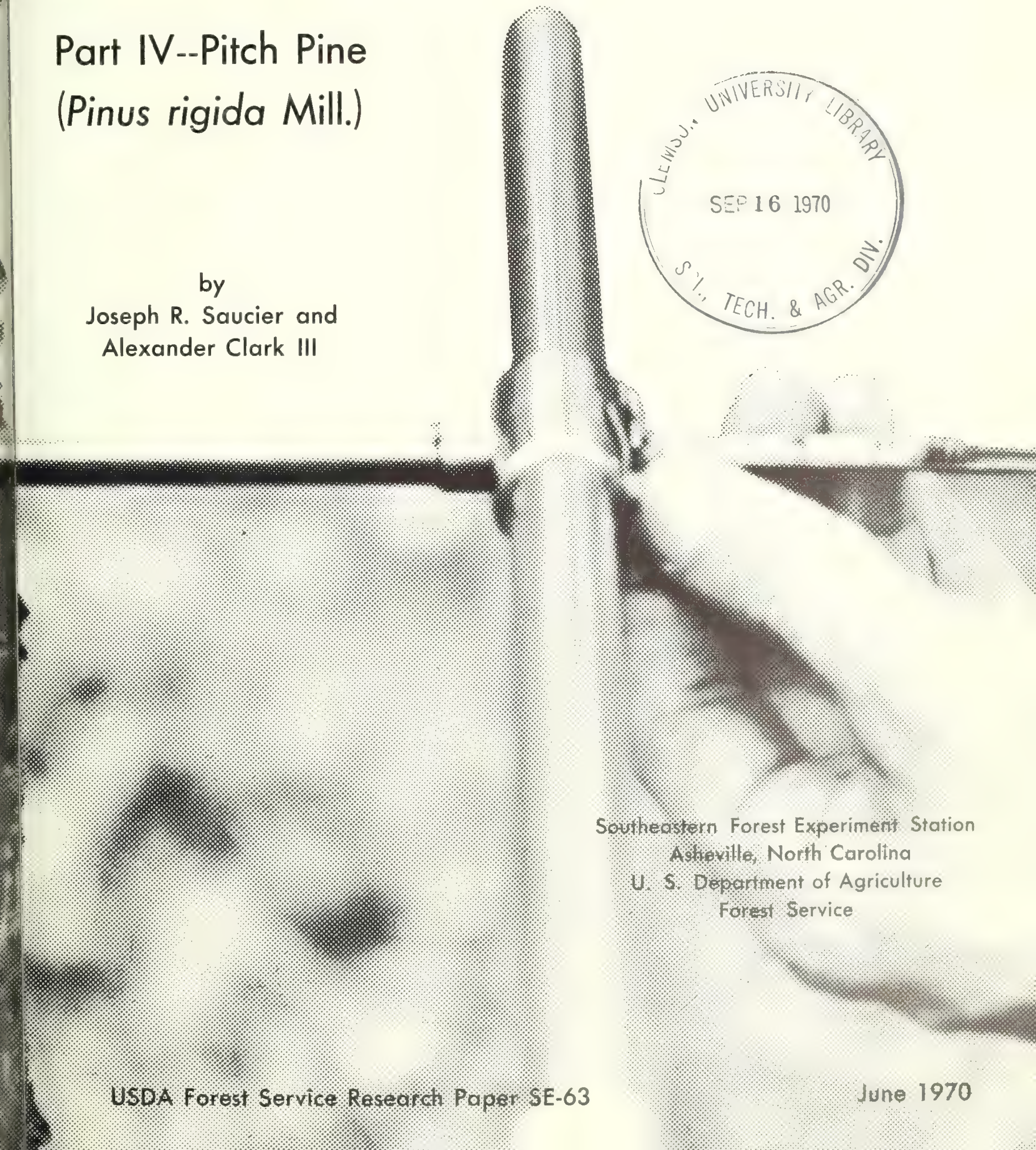
by
Joseph R. Saucier and
Alexander Clark III



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Forest Service

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June 1970

Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part IV--Pitch Pine (Pinus rigida Mill.)

by
Joseph R. Saucier, Wood Scientist
and
Alexander Clark III, Associate Wood Scientist
Forestry Sciences Laboratory
Athens, Georgia

INTRODUCTION

This report is the fourth in a series overing the wood density surveys of the ninor species of yellow pine in the Eastern Jnited States.[1] Literature review and hisorical information regarding these surveys vere presented in "Part I—Spruce Pine *Pinus glabra* Walt.)" by Taras and Saucier 1968) and will not be repeated here.

The objectives of the survey were:

(1) To obtain data that will provide an stimate of the average specific gravity of nextracted and extracted wood of each ninor species, and establish the degree of ariation about each mean.

(2) To evaluate increment core/tree pecific gravity relationships and develop egression equations for predicting tree pecific gravity from increment core specific ravity.

(3) To examine the geographic trends f wood specific gravity within the range of ach species, from east to west and from orth to south.

MATERIALS AND METHODS

Species

Pitch pine (*Pinus rigida* Mill.) grows over a wide geographic range, from central Maine south to western Virginia, to eastern Ohio, locally in eastern Kentucky and Tennessee, and in the mountains of North Carolina, South Carolina, and Georgia (fig. 1). Pitch pine is a tree of great diversity in form, habit, and development. In New England it is a small tree commonly found in the coastal districts and river valleys in company with gray birch (*Betula populifolia* Marsh.). In southern New Jersey it is a short, poorly formed tree found on excessively drained, sandy, sterile soils with scrub oak (*Quercus ilicifolia* Wangenh.). South through the Appalachian Mountains to northern Georgia, pitch pine of commercial importance grows at elevations between 1,400 to 4,500 feet. It often occurs in pure stands or with Table-Mountain pine (*Pinus pungens* Lamb.) on the drier southern slopes. Pitch pine reaches its best development (50 to 60 feet in height and 1 to 2 feet d.b.h.) in mixed hardwood stands where it is less tolerant than its associates—blackgum, red maple, various oaks, and hickories (fig. 2A). The largest living pitch pine measures 37.9 inches d.b.h. and is 91 feet tall (Pomeroy and Littlecott 1967).

The needles of pitch pine are 3 to 5 inches long, yellowish-brown, rigid, usually somewhat twisted, and occur in fascicles of

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[1] This study was conducted in cooperation with the rest Products Laboratory, the Northeastern Forest Exriment Station, the Southern Forest Experiment Station, d state forestry services, the pulp and paper industries, e southern pine plywood and sawmill industries, and merous private forest owners throughout the Southern d Eastern United States.

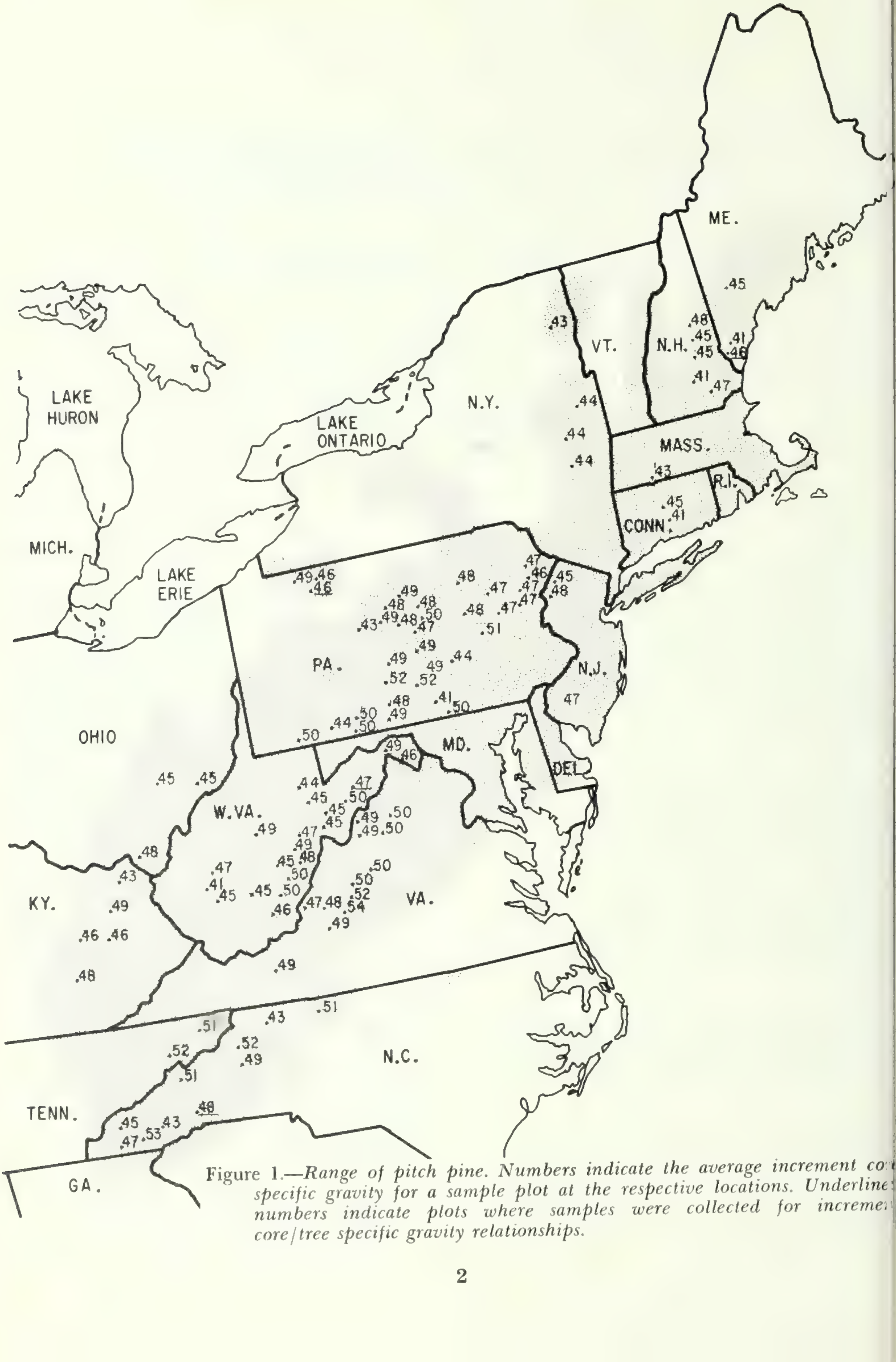

Figure 1.—*Range of pitch pine. Numbers indicate the average increment co specific gravity for a sample plot at the respective locations. Underline numbers indicate plots where samples were collected for incremen core/tree specific gravity relationships.*

three (fig. 2B). Cones are 2 to 3½ inches long, nearly sessile, ovoid, and usually persist for many years (fig. 2C). The cone scales are stiff and armed with a rigid prickle. The scientific name *rigida*, meaning stiff or rigid, refers to the cone scales. The bark on young stems is dark and scaly (fig. 2D); bark of mature trees is 1 to 2 inches thick at the base and forms smooth, flat, yellowish-brown plates separated by narrow, irregular fissures (Harlow and Harrar 1950).

Field Sampling Procedure

To meet the objectives of the study, 100 plots were sampled throughout the range of pitch pine. We calculated the number of trees sampled per plot had to be 20, in order to obtain an estimate of the mean specific gravity with a 95 percent confidence interval width of .02. The plots were selected randomly, with replacement, with the probability roughly proportional to the commercial forest area within Forest Survey Units[2] containing pitch pine. A 6-mile grid system was used to locate plots randomly within survey units.

At each plot location, a random azimuth was selected along which the first 20 trees, over 5.0 inches d.b.h. and showing no signs of heartrot, were sampled by removing two increment cores from opposite sides of each tree. The total height, merchantable height to a 4-inch top, and d.b.h. of each sample tree were recorded.

The trees to be used for analyzing increment core/tree specific gravity relationships were randomly selected at four locations within the range of pitch pine (fig. 1). Two increment cores were taken from each of 25 trees at each location before they were felled. Beginning at the butt end of the tree, 1-inch-thick disks were cut at 5-foot intervals to a 4-inch top. Total height and merchantable height to a 4-inch top were recorded, along with diameter of each disk.

Laboratory Procedures

The specific gravity of all unextracted and extracted increment cores was determined by the maximum moisture method described by Smith (1954). The specific gravity of wood disks was determined by the buoyancy method (Heinrichs 1954) and is based on green volume and ovendry weight.

Increment cores from all trees were extracted after unextracted specific gravity was determined. Extractions were made with a mixture of two parts benzene and one part ethyl alcohol for 24 hours. Following extraction the cores were saturated with water, and their specific gravity was determined by the maximum moisture method. No wood disks were extracted.

The increment cores from the trees collected to analyze increment core/tree specific gravity relationships were each divided into three equal parts, and the specific gravity of each segment was determined. The purpose was to obtain a weighted increment core specific gravity and to examine the relationship of parts (1/3 or 2/3) of whole increment cores to total tree specific gravity. Weighted total core specific gravity was determined by weighting the specific gravities of segments by the cross-sectional areas the segments represented.

The average specific gravity of the individual 5-foot bolts within each tree was computed as the mean of the bolt's terminal disks. The average specific gravity of the tree was determined by weighting the average bolt specific gravity by bolt volume. Formulas for all these computations are shown in the Appendix. A discussion of the analysis of the increment core/tree specific gravity relationship data is presented in an office report available from the Forestry Sciences Laboratory, Carlton Street, Athens, Georgia 30601.

RESULTS AND DISCUSSION

Pitch Pine Specific Gravity and Its Variation

The average specific gravity of *unextracted* pitch pine was .474, based on the average of two whole increment cores from 2,000 sample trees collected over the entire range of the species. The standard error of the mean increment core specific gravity was .001, and the standard deviation about the mean of the individual observations was .047.

The average specific gravity of *extracted* increment cores was .435; standard error was .001, and standard deviation of individuals was .035. The average specific gravity of unextracted and extracted increment cores by individual sample plots is shown in table 1. Table 1 also includes the average

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[2] Forest Survey Units are subdivisions of a state based in part on county boundaries and in part on physiography of the state. They are established for the purpose of sampling and reporting results efficiently.

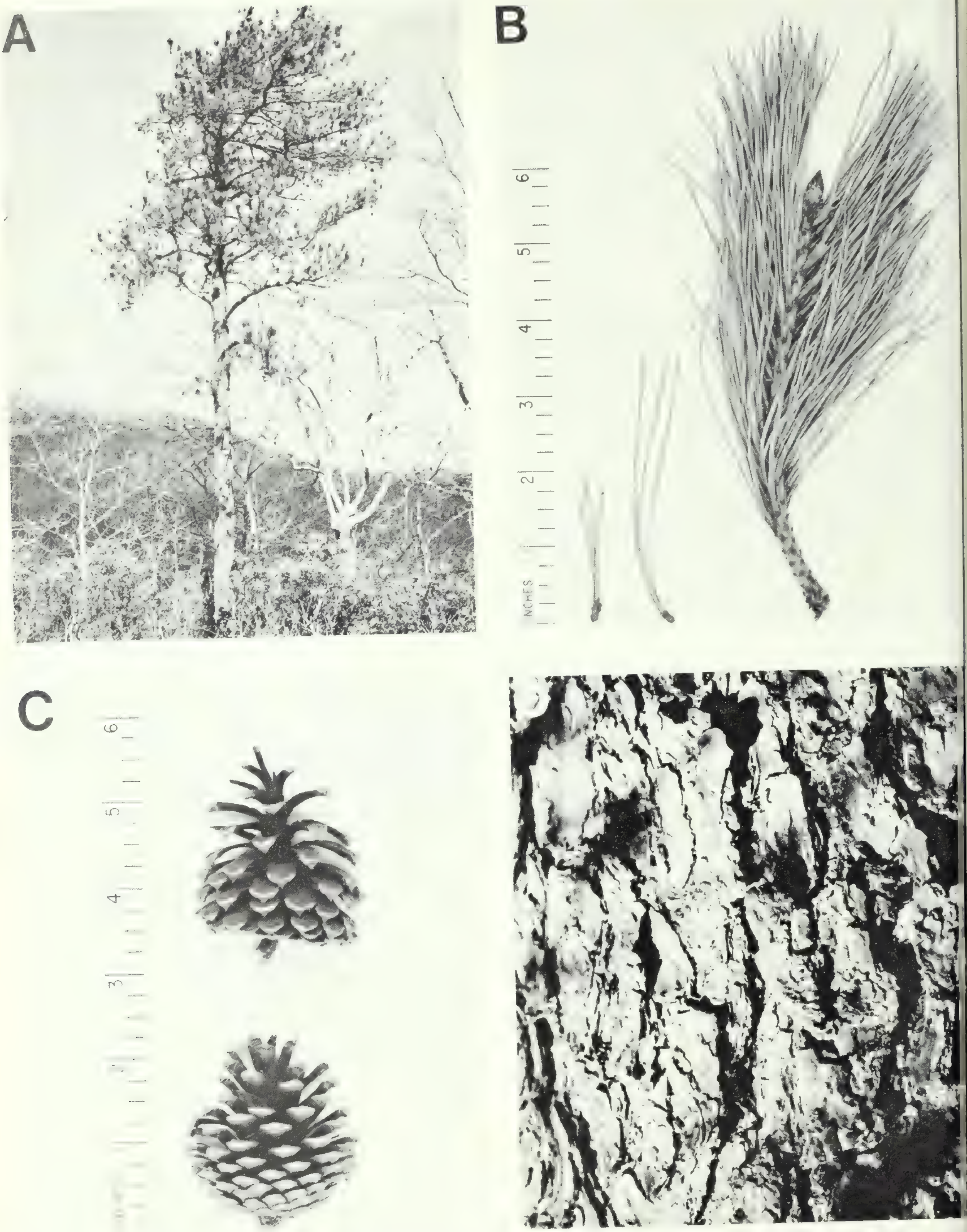

Figure 2.—*Botanical features of pitch pine:* (*A*) *mature tree,* (*B*) *needles,* (*C*) *cones,* (*D*) *bark of young tree.*

Table 1.—*Specific gravity of unextracted and extracted increment cores from pitch pine*

Plot number	County and state	Trees in sample	Mean d.b.h.	Mean age	Unextracted		Extracted		Difference between means
					Mean and standard error	Standard deviation	Mean and standard error	Standard deviation	
		Number	*Inches*	*Years*					*Percent*
1	Oxford, Me.	20	12.0	59	.451 (.007)	.030	.417 (.007)	.032	8.15
2	York, Me.	20	8.8	38	.412 (.007)	.030	.318 (.004)	.019	29.56
3	Carroll, N. H.	20	9.9	63	.475 (.009)	.040	.423 (.006)	.026	12.29
4	Carroll, N. H.	20	10.4	45	.446 (.010)	.044	.392 (.006)	.027	13.78
5	Belk Nap, N. H.	20	11.2	63	.454 (.008)	.036	.403 (.006)	.025	12.66
6	Merr Mack, N. H.	20	12.6	46	.405 (.010)	.044	.363 (.008)	.035	11.57
7	Rockingham, N. H.	20	12.5	73	.467 (.014)	.061	.413 (.009)	.041	13.08
8	Hamden, Mass.	20	8.2	32	.430 (.006)	.026	.403 (.006)	.028	6.70
9	Hartford, Conn.	20	10.1	52	.455 (.008)	.034	.417 (.007)	.030	9.11
10	Middlesex, Conn.	20	8.9	32	.408 (.005)	.024	.383 (.005)	.020	6.53
11	Essex, N. Y.	20	8.9	41	.431 (.010)	.045	.393 (.007)	.030	9.67
12	Washington, N. Y.	20	9.2	48	.445 (.009)	.039	.404 (.006)	.025	10.15
13	Schenectady, N. Y.	20	9.8	39	.443 (.007)	.030	.399 (.004)	.018	11.03
14	Albany, N. Y.	20	9.6	43	.436 (.010)	.043	.404 (.007)	.032	7.92
15	Sussex, N. J.	20	6.7	49	.454 (.006)	.027	.429 (.006)	.028	5.83
16	Salem, N. J.	20	10.1	48	.467 (.009)	.038	.438 (.004)	.019	6.62
17	Pike, Pa.	20	11.9	66	.455 (.013)	.056	.416 (.007)	.033	9.38
18	Pike, Pa.	20	15.1	97	.473 (.006)	.026	.430 (.007)	.029	10.00
19	Pike, Pa.	20	11.3	73	.470 (.008)	.037	.428 (.007)	.029	9.81
20	Carbon, Pa.	20	7.7	53	.465 (.010)	.043	.425 (.009)	.041	9.41
21	Monroe, Pa.	20	7.8	47	.472 (.010)	.043	.430 (.006)	.026	9.77
22	Sussex, N. J.	20	11.6	101	.479 (.007)	.032	.435 (.009)	.038	10.11
23	Sullivan, Pa.	20	10.0	84	.478 (.007)	.031	.431 (.007)	.031	10.90
24	Luzerne, Pa.	20	9.1	80	.473 (.008)	.035	.433 (.009)	.040	9.24
25	Columbia, Pa.	20	8.8	60	.476 (.009)	.039	.417 (.008)	.038	14.15
26	Schuylkill, Pa.	20	9.9	74	.505 (.009)	.038	.451 (.007)	.030	11.97
27	Dauphin, Pa.	20	9.7	43	.444 (.008)	.035	.408 (.007)	.029	8.82
28	Clinton, Pa.	20	11.0	83	.503 (.014)	.060	.453 (.008)	.035	11.04
29	Clinton, Pa.	20	12.7	80	.473 (.007)	.032	.449 (.004)	.016	5.35
30	Clinton, Pa.	20	11.0	70	.478 (.012)	.054	.439 (.009)	.039	8.88
31	Clinton, Pa.	20	9.5	76	.489 (.005)	.023	.444 (.004)	.017	10.14
32	Clinton, Pa.	20	9.9	74	.478 (.010)	.043	.455 (.008)	.037	5.05
33	Clinton, Pa.	20	11.5	78	.482 (.006)	.027	.460 (.007)	.030	4.78
34	Clinton, Pa.	20	14.3	113	.490 (.007)	.029	.453 (.007)	.030	8.17
35	Clinton, Pa.	20	8.2	40	.427 (.007)	.031	.410 (.005)	.023	4.15
36	Mifflin, Pa.	20	10.7	110	.490 (.006)	.027	.453 (.006)	.027	8.17
37	Huntington, Pa.	20	13.7	96	.486 (.009)	.038	.444 (.008)	.037	9.46
38	Huntington, Pa.	20	14.9	100	.516 (.009)	.040	.462 (.009)	.038	11.69
39	Fulton, Pa.	20	9.2	71	.495 (.009)	.042	.446 (.006)	.025	10.99
40	Fulton, Pa.	20	9.7	53	.477 (.009)	.040	.442 (.007)	.029	7.92
41	McKean, Pa.	20	11.3	74	.465 (.008)	.034	.438 (.007)	.032	6.16
42	McKean, Pa.	20	10.7	66	.485 (.013)	.058	.437 (.005)	.023	10.98
43	Bedford, Pa.	20	8.1	49	.497 (.010)	.045	.452 (.007)	.031	9.96
44	Perry, Pa.	20	13.8	101	.486 (.009)	.040	.438 (.007)	.033	10.96
45	Perry, Pa.	20	11.8	91	.518 (.007)	.032	.477 (.006)	.028	8.60
46	Adams, Pa.	20	9.2	79	.503 (.008)	.036	.471 (.007)	.030	6.79
47	Adams, Pa.	20	9.9	66	.510 (.008)	.034	.462 (.005)	.021	10.39
48	Bedford, Pa.	20	11.5	92	.496 (.008)	.036	.437 (.005)	.023	13.50
49	Berkeley, W. Va.	20	8.5	37	.457 (.011)	.050	.409 (.005)	.022	11.74
50	Morgan, W. Va.	20	11.1	61	.485 (.006)	.028	.454 (.006)	.029	6.83
51	Hardy, W. Va.	20	9.0	62	.498 (.011)	.049	.446 (.008)	.034	11.66
52	Page, Va.	20	9.4	66	.504 (.007)	.033	.463 (.007)	.033	8.86
53	Page, Va.	20	10.9	63	.497 (.014)	.064	.447 (.005)	.022	11.19
54	Page, Va.	20	8.5	41	.487 (.010)	.045	.455 (.008)	.035	7.03
55	Botetourt, Va.	20	11.7	72	.537 (.009)	.038	.488 (.006)	.029	10.04
56	Rockbridge, Va.	20	11.5	67	.527 (.009)	.041	.486 (.008)	.035	8.44
57	Rockbridge, Va.	20	9.4	59	.501 (.012)	.053	.454 (.006)	.028	10.35
58	Rockbridge, Va.	20	9.5	58	.479 (.007)	.033	.440 (.006)	.025	8.86
59	Botetourt, Va.	20	9.3	75	.491 (.007)	.033	.456 (.008)	.034	7.68
60	Pulaski, Va.	20	8.1	42	.469 (.008)	.034	.429 (.007)	.033	9.32
61	Alleghany, Va.	20	8.1	58	.504 (.010)	.043	.454 (.005)	.024	11.01
62	Augusta, Va.	20	9.2	65	.487 (.011)	.048	.448 (.008)	.036	8.71
63	Pendleton, W. Va.	20	7.7	66	.455 (.009)	.039	.436 (.008)	.034	4.36
64	Rockingham, Va.	20	9.6	74	.486 (.009)	.038	.446 (.007)	.032	8.97
65	Pendleton, W. Va.	20	8.3	55	.453 (.007)	.032	.415 (.006)	.028	9.16
66	Pendleton, W. Va.	20	8.9	87	.470 (.008)	.036	.440 (.006)	.027	6.82
67	Pocahontas, W. Va.	20	11.1	83	.490 (.008)	.034	.460 (.007)	.030	6.52

Table 1.—*Specific gravity of unextracted and extracted increment cores from pitch pine (continued)*

Plot number	County and state	Trees in sample	Mean d.b.h.	Mean age	Unextracted		Extracted		Difference between means
					Mean and standard error	Standard deviation	Mean and standard error	Standard deviation	
		Number	*Inches*	*Years*					*Percent*
68	Pocahontas, W. Va.	20	8.4	56	.448 (.006)	.027	.426 (.007)	.030	5.16
69	Tucker, W. Va.	20	8.9	31	.438 (.004)	.018	.415 (.004)	.019	5.54
70	Tucker, W. Va.	20	8.1	35	.451 (.008)	.034	.431 (.005)	.022	4.64
71	Pocahontas, W. Va.	20	10.0	78	.502 (.012)	.054	.450 (.007)	.030	11.56
72	Pocahontas, W. Va.	20	10.6	80	.483 (.006)	.026	.451 (.006)	.028	7.10
73	Greenbrier, W. Va.	20	9.5	59	.501 (.006)	.025	.469 (.006)	.029	6.82
74	Monroe, W. Va.	20	11.0	49	.465 (.005)	.024	.431 (.006)	.029	7.89
75	Fayette, W. Va.	20	9.9	37	.446 (.005)	.022	.416 (.004)	.019	7.21
76	Kanawha, W. Va.	20	7.3	43	.475 (.011)	.048	.457 (.010)	.045	3.94
77	Washington, Ohio	20	8.2	36	.451 (.005)	.024	.413 (.004)	.020	9.20
78	Perry, Ohio	20	6.2	24	.446 (.006)	.029	.417 (.006)	.027	6.95
79	Lawrence, Ohio	20	9.0	44	.481 (.010)	.044	.438 (.007)	.032	9.82
80	Braxton, W. Va.	20	9.7	70	.487 (.007)	.031	.452 (.006)	.027	7.74
81	Somerset, Pa.	20	6.3	38	.445 (.009)	.040	.405 (.006)	.026	9.88
82	Fayette, Pa.	20	9.5	75	.496 (.010)	.043	.455 (.007)	.031	9.01
83	Boone, W. Va.	20	8.7	31	.446 (.009)	.042	.413 (.009)	.038	7.99
84	Boone, W. Va.	20	10.2	21	.405 (.005)	.021	.387 (.004)	.017	4.65
85	Greenup, Ky.	20	8.8	29	.434 (.005)	.024	.401 (.004)	.016	8.23
86	Rowan, Ky.	20	11.0	38	.489 (.014)	.061	.429 (.006)	.026	13.99
87	Wolfe, Ky.	20	8.5	34	.463 (.009)	.041	.426 (.005)	.021	8.69
88	Powell, Ky.	20	7.6	28	.455 (.008)	.037	.418 (.006)	.027	8.85
89	Jackson, Ky.	20	7.3	31	.485 (.008)	.034	.446 (.007)	.031	8.74
90	Green, Tenn.	20	8.7	38	.519 (.007)	.032	.477 (.007)	.032	8.81
91	Sullivan, Tenn.	20	11.1	70	.513 (.009)	.039	.477 (.007)	.032	7.55
92	Stokes, N. C.	20	13.3	97	.513 (.011)	.051	.454 (.005)	.021	13.00
93	Wilkes, N. C.	20	7.8	22	.435 (.007)	.030	.405 (.006)	.028	7.41
94	Caldwell, N. C.	20	10.7	53	.489 (.008)	.036	.458 (.007)	.030	6.77
95	Caldwell, N. C.	20	10.3	77	.521 (.013)	.057	.470 (.008)	.037	10.85
96	Madison, N. C.	20	8.6	45	.512 (.008)	.035	.463 (.005)	.023	10.58
97	Macon, N. C.	20	10.0	34	.430 (.008)	.037	.403 (.008)	.038	6.70
98	Graham, N. C.	20	10.0	33	.451 (.005)	.024	.425 (.005)	.024	6.12
99	Cherokee, N. C.	20	8.0	46	.526 (.008)	.037	.478 (.006)	.026	10.04
100	Cherokee, N. C.	20	8.2	29	.468 (.007)	.032	.439 (.007)	.032	6.61
	Total	2,000	9.9	59	.474 (.001)	.047	.435 (.001)	.035	8.97

d.b.h., age, and percentage difference resulting from extraction for each plot. The specific gravity of unextracted cores was 9 percent higher than extracted core specific gravity. This is considerably higher than the 6 to 7.5 percent difference reported for the four major species of southern yellow pine, spruce pine, and Table-Mountain pine (Taras and Saucier 1967, 1968; Clark and Saucier 1969) but is less than 9.7 percent difference reported for Choctawhatchee sand pine (Clark and Taras 1969). The average increment core specific gravity of pitch pine trees in the 5.0 to 8.9 inch diameter class decreased 7.8 percent when extractives were removed; trees in the 9.0 to 14.9 inch class decreased 9.6 percent, and those in the 15.0+ inch class decreased 10.5 percent.

The estimated tree specific gravities for pitch pine were obtained by using the following regression equation:

$$\text{Tree specific gravity (Y)} = 0.1943 + 0.54067(\text{sp. gr., 2 extracted cores} + 2.01173(1/\text{age}) \quad (1$$

When the specific gravity of 2,000 trees sam pled by increment cores was adjusted t whole tree specific gravity by using equa tion (1), the average tree specific gravit was .471, with a standard error of .002.

The specific gravity of unextracted i crement cores and the estimated tree sp cific gravity by three diameter classes (5 to 8.9 inches; 9.0 to 14.9 inches; and 15.0- inches) are presented in table 2 for eac Forest Survey Unit sampled in this surve

Analyses of variance for unextracted ar extracted increment core specific gravi and tests of significance for locations ar trees within a location are presented i table 3. The unextracted and extracted i crement core specific gravity of pitch pi

Table 2.—*Specific gravity for pitch pine by states and by Forest Survey Units within states*

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Unextracted increment core specific gravity		Estimated tree specific gravity[1] mean and standard error
				Mean and standard error	Standard deviation	
	Number	*Inches*	*Number*			
Connecticut						
	2	5.0-8.9	16	.437 (.020)	.037	.470 (.010)
		9.0-14.9	24	.428 (.026)	.031	.457 (.008)
		15.0+	0	----	----	-
Kentucky						
Northern Cumberland (1)	4	5.0-8.9	47	.451 (.009)	.032	.498 (.011)
		9.0-14.9	30	.474 (.013)	.061	.477 (.008)
		15.0+	3	.463 (.017)	.032	.448 (.019)
Southern Cumberland (4)	1	5.0-8.9	17	.480 (.008)	.033	.504 (.012)
		9.0-14.9	3	.513 (.024)	.042	.506 (.020)
		15.0+	0	----	----	-- -
State total	5	5.0-8.9	64	.459 (.006)	.033	.499 (.010)
		9.0-14.9	33	.478 (.011)	.061	.480 (.008)
		15.0+	3	.463 (.018)	.032	.448 (.019)
Maine						
	2	5.0-8.9	18	.418 (.021)	.039	.455 (.009)
		9.0-14.9	17	.443 (.018)	.032	.457 (.009)
		15.0+	5	.442 (.016)	.035	.443 (.015)
Massachusetts						
	1	5.0-8.9	11	.428 (.009)	.031	.477 (.012)
		9.0-14.9	9	.433 (.008)	.023	.474 (.013)
		15.0+	0	----	----	-- -
New Hampshire						
	5	5.0-8.9	30	.453 (.019)	.063	.464 (.007)
		9.0-14.9	56	.444 (.012)	.047	.444 (.005)
		15.0+	14	.463 (.011)	.033	.439 (.009)
New Jersey						
	3	5.0-8.9	25	.455 (.002)	.026	.469 (.007)
		9.0-14.9	34	.474 (.004)	.035	.460 (.006)
		15.0+	1	.478 (----)	----	.458 (----)
New York						
East Adirondack (4)	1	5.0-8.9	10	.424 (.007)	.022	.466 (.012)
		9.0-14.9	10	.437 (.017)	.053	.451 (.011)
		15.0+	0	----	----	- --
Capital District (7)	3	5.0-8.9	24	.445 (.009)	.038	.468 (.008)
		9.0-14.9	36	.439 (.004)	.039	.455 (.007)
		15.0+	0	----	----	- --
State total	4	5.0-8.9	34	.439 (.007)	.036	.467 (.008)
		9.0-14.9	46	.439 (.003)	.049	.454 (.006)
		15.0+	0	----	- -	-- -
North Carolina						
Piedmont (3)	1	5.0-8.9	1	.480 (----)	----	.468 (----)
		9.0-14.9	14	.515 (.015)	.056	.461 (.009)
		15.0+	5	.515 (.012)	.027	.458 (.015)
Mountain (4)	8	5.0-8.9	78	.476 (.015)	.052	.499 (.009)
		9.0-14.9	75	.482 (.013)	.064	.484 (.005)
		15.0+	7	.477 (.037)	.066	.475 (.013)
State total	8	5.0-8.9	79	.476 (.015)	.052	.498 (.008)
		9.0-14.9	89	.487 (.011)	.064	.480 (.004)
		15.0+	12	.493 (.021)	.057	.468 (.010)
Ohio						
South-central (1)	1	5.0-8.9	11	.471 (.014)	.046	.482 (.011)
		9.0-14.9	9	.494 (.010)	.031	.473 (.011)
		15.0+	0	----	----	----
Southeastern (2)	2	5.0-8.9	31	.447 (.001)	.026	.501 (.012)
		9.0-14.9	9	.455 (.009)	.027	.462 (.012)
		15.0+	0	----	----	- -
State total	3	5.0-8.9	42	.453 (.005)	.034	.496 (.010)
		9.0-14.9	18	.474 (.014)	.036	.467 (.008)
		15.0+	0	----	--	

Table 2.—*Specific gravity for pitch pine by states and by Forest Survey Units within states (continued)*

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Unextracted increment core specific gravity		Estimated tree specific gravity[1] mean and standard error
				Mean and standard error	Standard deviation	
	Number	*Inches*	*Number*			
Pennsylvania						
Alleghany N.F. (1)	2	5.0-8.9	7	.473 (.024)	.027	.470 (.013)
		9.0-14.9	32	.478 (.005)	.053	.460 (.006)
		15.0+	1	.400 (----)	- -	.425 (----)
Southwestern (4)	4	5.0-8.9	42	.477 (.020)	.051	.478 (.006)
		9.0-14.9	36	.493 (.002)	.036	.457 (.006)
		15.0+	2	.479 (.027)	.039	.444 (.024)
North-central (5)	9	5.0-8.9	40	.470 (.017)	.038	.474 (.006)
		9.0-14.9	126	.480 (.006)	.053	.462 (.003)
		15.0+	14	.480 (.003)	.035	.458 (.009)
South-central (6)	8	5.0-8.9	33	.472 (.013)	.042	.473 (.006)
		9.0-14.9	97	.492 (.006)	.049	.463 (.004)
		15.0+	30	.499 (.012)	.048	.455 (.007)
Northeastern (7)	8	5.0-8.9	70	.477 (.005)	.043	.469 (.004)
		9.0-14.9	73	.475 (.006)	.046	.453 (.004)
		15.0+	17	.457 (.011)	.034	.445 (.008)
Southeastern (8)	2	5.0-8.9	22	.506 (.004)	.038	.486 (.008)
		9.0-14.9	16	.513 (.002)	.036	.467 (.009)
		15.0+	2	.469 (.004)	.008	.453 (.024)
State total	33	5.0-8.9	214	.478 (.003)	.037	.474 (.003)
		9.0-14.9	380	.484 (.001)	.045	.460 (.002)
		15.0+	66	.481 (.001)	.044	.452 (.005)
Tennessee						
Eastern (5)	2	5.0-8.9	16	.510 (.025)	.041	.510 (.011)
		9.0-14.9	23	.519 (.008)	.031	.488 (.008)
		15.0+	1	.556 (----)	- - -	.473 (----)
Virginia						
Northern Mountain (4)	11	5.0-8.9	110	.492 (.008)	.041	.485 (.004)
		9.0-14.9	98	.503 (.007)	.053	.470 (.004)
		15.0+	12	.512 (.010)	.047	.468 (.010)
Southern Mountain (5)	1	5.0-8.9	7	.506 (.017)	.044	.480 (.013)
		9.0-14.9	13	.483 (.008)	.030	.462 (.009)
		15.0+	0	----	----	----
State total	12	5.0-8.9	117	.493 (.007)	.041	.485 (.004)
		9.0-14.9	111	.500 (.008)	.045	.469 (.003)
		15.0+	12	.512 (.014)	.047	.468 (.010)
West Virginia						
Northeastern (2)	13	5.0-8.9	122	.463 (.005)	.034	.477 (.005)
		9.0-14.9	132	.477 (.007)	.049	.465 (.003)
		15.0+	6	.481 (.018)	.057	.459 (.014)
Southern (3)	6	5.0-8.9	54	.453 (.014)	.040	.496 (.009)
		9.0-14.9	62	.461 (.013)	.038	.480 (.006)
		15.0+	4	.426 (.012)	.032	.459 (.017)
State total	19	5.0-8.9	176	.460 (.004)	.036	.483 (.005)
		9.0-14.9	194	.472 (.004)	.046	.470 (.003)
		15.0+	10	.459 (.009)	.053	.459 (.010)
All States	100	5.0-8.9	842	.468 (.001)	.043	.482 (.005)
		9.0-14.9	1034	.477 (.001)	.045	.465 (.001)
		15.0+	124	.480 (.002)	.044	.454 (.003)
Total all classes	100		2,000	.474 (.001)	.047	.471 (.002)

[1] Estimates were made with equation (1):

$$Y = 0.19438 + 0.54067\,(\text{sp. gr., 2 extracted cores}) + 2.01173\,(1/\text{age}).$$

Table 3.—*Analyses of variance for pitch pine specific gravity and, tests of significance for locations and trees within a location*

Source	d.f.	Unextracted		Extracted	
		MS	F ratio	MS	F ratio
Among locations	99	0.0326	12.07**	0.0250	14.71**
Among trees within locations	1,900	0.0027	3.37**	0.0017	4.25**
Among cores within trees	2,000	0.0008		0.0004	
Total	3,999				

**Significant at the .01 probability level.

varied more between plots than among trees within a plot, as was found for spruce pine and Table-Mountain pine (Taras and Saucier 1968; Clark and Saucier 1969).

The data in table 1 are also shown in figure 1 to illustrate specific gravity changes with geographic location. Correlation analyses indicated that unextracted and extracted increment core specific gravities were significantly associated with latitude and longitude. But examination of the data in figure 1 suggested that the differences in specific gravity were not continuous in a north-south or east-west trend, but rather varied between two discrete regional areas—the northeast (New England and New York) and the remainder of the range.

To examine regional changes in specific gravity, the range of pitch pine was divided into four regions: (1) Northeast (New England and New York); (2) North Central (Pennsylvania and New Jersey); (3) Central (Virginia, West Virginia, Maryland, Ohio, and Kentucky); (4) Southern (North Carolina, South Carolina, Tennessee, and Georgia).

With an analysis of covariance to adjust for the effects of age and d.b.h., unextracted and extracted increment core specific gravities were found to vary significantly among geographic regions (tables 5 and 6, Appendix). The adjusted mean unextracted specific gravity of the Northeast region (table 4) is considerably lower than the adjusted mean unextracted specific gravities of the other three regions. The average observed unextracted increment core specific gravity of the Northeast was .440 and the Southern region averaged .409, a difference of 11.1 percent based on the Northeast value. After extraction, the mean extracted increment core specific gravity of the Northeast region was still significantly lower than all other regions; the average in the Northeast region was 8.8 percent less than the average of trees sampled in the other geographic regions.

These results indicate that two races or ecotypes of pitch pine might exist. One race occurs on sandy, outwash plains of glacial origin along the coast and in river valleys in New England and New York, and the other is found on shallow soils on steep slopes, ridges, and plateaus throughout the Appalachian Mountains.

Table 4.—*Mean d.b.h., age, and increment core specific gravity for geographic regions. (Increment core specific gravity values were adjusted by covariance analyses for the effects of age and d.b.h.)*

Geographic regions	Trees sampled	Mean d.b.h.	Mean age	Mean increment core specific gravity			
				Unextracted		Extracted	
				Unadjusted	Adjusted	Unadjusted	Adjusted
	Number	*Inches*	*Years*				
Northeast	280	10.2	48	.440	.448	.395	.407
North Central	720	10.5	74	.480	.471	.440	.433
Central	780	9.2	52	.475	.479	.439	.441
Southern	220	9.7	49	.489	.495	.450	.455
Species average		9.9	59	.474	.474	.439	.435

Increment Core / Tree Specific Gravity Relationships—Simple Linear and Multiple Regression Analyses

A discussion of the increment core/tree specific gravity relationships is given in an office report available upon request and will not be treated in detail here. All regression equations developed from these data for predicting tree specific gravity of pitch pine are presented in table 7 in the Appendix. Table 8 in the Appendix contains the means and standard deviations of all the independent variables used to analyze increment core/tree specific gravity relationships.

From these data, the best equation developed for predicting tree specific gravity of pitch pine was:

$$Y = 0.22565 + 0.53777(\text{sp. gr., outer } 2/3 \text{ of 2 extracted cores}) + 0.55637 (1/\text{age}) - 0.00149(\text{d.b.h.}) \quad (2)$$

This equation had a correlation coefficient of .78 and was associated with 61 percent of the variation about regression. The standard error about regression for equation (2) was .017.

Equation (1) was used in this study to adjust increment core specific gravity of pitch pine to tree specific gravity. This equation was used instead of the best one developed because the specific gravity was determined for only whole cores in the large sample. Equation (1) had a correlation coefficient of .71 and was associated with 50 percent of the variation about regression.

Relationship of Unextracted and Extracted Specific Gravity

The specific gravity of all increment cores was determined in both the unextracted and extracted condition. From these data, a regression equation for predicting extracted specific gravity from unextracted specific gravity was developed. Equation (3) has a correlation coefficient of .82 and a standard error about regression of .021:

$$Y = 0.11241 + 0.68125 X_1 \quad (3)$$

Where: Y = specific gravity of 2 extracted increment cores
X_1 = specific gravity of 2 unextracted increment cores

Similar high correlations have been reported for the relationship between unextracted and extracted increment core specific gravity for other minor species of southern yellow pine (Taras and Saucier 1968; Clark and Taras 1969; Clark and Saucier 1969).

SUMMARY AND CONCLUSIONS

The average specific gravity of pitch pine was .474. The same increment cores had an average specific gravity of .435, a decrease of 9 percent, after extraction. An equation is presented for predicting extracted increment core specific gravity from unextracted increment core specific gravity.

Unextracted and extracted increment core specific gravities of pitch pine were significantly correlated with latitude and longitude. The average unextracted increment core specific gravity of pitch pine in New England and New York was 11.1 percent less than the average increment core specific gravity of pitch pine in North Carolina, South Carolina, and Tennessee. After the extractives were removed, the extracted increment core specific gravity of the Northeast region was still significantly lower than all other regions. These regional differences in increment core specific gravity indicated the possible existence of two races or ecotypes of pitch pine. One race occurs on sandy, outwashed plains in New England and New York, while the other occurs on shallow soil on the ridges and plateaus of the Appalachian Mountains.

The best equation developed for predicting pitch pine tree specific gravity involved three independent variables: (1) specific gravity of the outer 2/3 of 2 extracted cores, (2) 1/age, and (3) d.b.h. These variables explained 61 percent of the variation in tree specific gravity. Since the increment cores taken in the survey were not segmented when their specific gravity was determined, equation (1) was used to adjust pitch pine increment core specific gravity to tree specific gravity. The variables in the equation accounted for 50 percent of the variation about regression.

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APPENDIX

Computational Procedures

1. Increment core specific gravity $= \dfrac{\text{ovendry weight of core}}{\text{green weight of core} - .3464\,(\text{ovendry weight of core})}$

2. Disk specific gravity $= \dfrac{\text{ovendry weight of disk}}{\text{displaced volume of disk}}$

3. Bolt specific gravity $= \dfrac{\text{specific gravity top disk} + \text{specific gravity bottom disk}}{2}$

4. Tree specific gravity $= \dfrac{\sum_{1-n} (\text{bolt volume} \times \text{bolt specific gravity})}{\sum_{1-n} \text{bolt volumes}}$

5. Bolt volume = bolt length, feet $\times \left[\dfrac{.005454\,(\text{d.i.b.})_t^2 + .005454\,(\text{d.i.b.})_b^2}{2}\right]$

   where: t = top of bolt
   b = base of bolt

6. (a) Mean core specific gravity $\bar{x} = \dfrac{\Sigma_i \Sigma_j X_{ij}}{m_1 n_1}$

   where: X_{ij} = the core specific gravity for the jth tree at the ith location
   m_1 = number of trees at each location
   n_1 = number of locations

   (b) The standard deviation of individuals was estimated from the sample range of the core specific gravitie using the tabular values of the ratio of the standard deviation to the range.

7. Tree specific gravities were estimated from regression by:

   (a) Tree specific gravity (Y) = $b_0 + b_1X_1 + b_2X_2$

   where: Y = tree specific gravity
   X_1 = average specific gravity of 2 extracted cores
   X_2 = 1/age

   (b) The standard error of the predicted mean tree specific gravity was estimated by--

$$S_{\hat{y}} = \left[S^2_{y.x} \left(\frac{1}{m_2 n_2} + C_{11}(\bar{x}_{1,1} - \bar{x}_{1,2})^2 + C_{22}(\bar{x}_{2,1} - \bar{x}_{2,2})^2 + 2C_{12}(\bar{x}_{1,1} - \bar{x}_{1,2})(\bar{x}_{2,1} - \bar{x}_{2,2}) \right) + \frac{S^2_y}{m_1 n_1} \right]^{\frac{1}{2}}$$

   where: $S^2_{y.x}$ = residual mean squares

   S^2_y = variance of y prior to adjustment for regression

   $\bar{x}_{1,1}$ = mean core specific gravity of trees from which only cores were collected, sample (1)

   $\bar{x}_{1,2}$ = mean core specific gravity of trees collected for tree-core relationships, sample (2)

   $\bar{x}_{2,1}$ = mean d.b.h./age for sample (1)

   $\bar{x}_{2,2}$ = mean d.b.h./age for sample (2)

   m_1 = number of trees at each location, sample (1)

   m_2 = number of trees at each location, sample (2)

   n_1 = number of locations, sample (1)

   n_2 = number of locations, sample (2)

(c) The standard error of the core mean was approximated by the following computation when the variances were pooled to obtain the mean core specific gravity of more than one location:

$$\text{standard error} = \sqrt{\frac{K}{(\Sigma n_i)^2}\left(\frac{\Sigma S_i^2 + \bar{x}^2 \Sigma n_i^2 - 2\bar{x}\Sigma n_i S_i}{K-1}\right)}$$

where: K = the number of locations at which trees were bored for specific gravity

S_i = the sum of specific gravities of cores at the ith location ($= \Sigma_j X_{ij}$)

(d) When variances were not pooled the standard error of the mean was approximated by--

$$\text{standard error} = \frac{S}{\sqrt{n}}$$

where: S = standard deviation estimated from the sample range of core specific gravities

n = number of observations in sample

$$\text{Percentage difference in specific gravity due to extraction} = \frac{\text{unextracted core sp. gr.} - \text{extracted core sp. gr.}}{\text{extracted core sp. gr.}} \times 100$$

Table 5.—*Analysis of covariance for pitch pine unextracted increment core specific gravity, adjusted for age and d.b.h., and test of significance for geographic regions*

Source	d.f.	Y Y	Sums-squares (due to regression)	Sums-squares (about regression)	d.f.	Mean squares
Among regions	3	0.4052				
Within regions	1,996	3.7444	0.4422	3.3022	1,994	0.0017
Treatments + error	1,999	4.1496	0.5392	3.6104	1,997	
Region means adjusted for age and d.b.h.				0.3082	3	0.1027**

**Significant at the .01 probability level.

Table 6.—*Analysis of covariance for pitch pine extracted increment core specific gravity, adjusted for age and d.b.h., and test of significance for geographic regions*

Source	d.f.	Y Y	Sums-squares (due to regression)	Sums-squares (about regression)	d.f.	Mean squares
Among regions	3	0.4365				
Within regions	1,996	2.3888	0.2795	2.1093	1,994	0.0011
Treatments + error	1,999	2.8253	0.3714	2.4539	1,997	
Region means adjusted for age and d.b.h.				0.3446	3	0.1149**

**Significant at the .01 probability level.

nation, and standard errors about regressions for pitch pine increment

Regression equations	r	r²	Standard error
Tree specific gravity (Y):			
Y = 0.22565 + 0.53777 (sp. gr., outer 2/3 of 2 extracted cores) + 0.55437 (1/age) — 0.00149 (d.b.h.)	0.78	0.61	0.017
Y = 0.23549 + 0.56677 (weighted sp. gr., 2 extracted cores) — 0.00021 (total height) — 0.00167 (d.b.h.)	0.77	0.59	0.018
Y = 0.23491 + 0.54764 (sp. gr., outer 2/3 of 2 extracted cores) — 0.00198 (d.b.h.)	0.77	0.59	0.017
Y = 0.24480 + 0.53068 (weighted sp. gr., 2 extracted cores) — 0.00205 (d.b.h.)	0.76	0.58	0.018
Y = 0.28272 + 0.42604 (weighted sp. gr., 1 extracted core) + 0.54520 (1/age) — 0.00198 (d.b.h.)	0.74	0.55	0.019
Y = 0.29493 + 0.44659 (sp. gr., outer 1/3 of 2 extracted cores) — 0.03044 (d.b.h./age) — 0.00068 (total height)	0.74	0.55	0.019
Y = 0.20764 + 0.56885 (weighted sp. gr., 2 extracted cores)	0.74	0.55	0.018
Y = 0.19824 + 0.58592 (sp. gr., outer 2/3 of 2 extracted cores)	0.74	0.55	0.018
Y = 0.29205 + 0.44861 (sp. gr., outer 1/3 of 2 extracted cores) + 0.00073 (total height)	0.74	0.55	0.018
Y = 0.27653 + 0.42636 (sp. gr., outer 2/3 of 1 extracted core) + 0.72749 (1/age) — 0.00180 (d.b.h.)	0.74	0.55	0.018
Y = 0.29224 + 0.43504 (weighted sp. gr., 1 extracted core) — 0.00247 (d.b.h.)	0.73	0.53	0.019
Y = 0.29038 + 0.43585 (sp. gr., outer 2/3 of 1 extracted core) — 0.00246 (d.b.h.)	0.73	0.53	0.019
Y = 0.25654 + 0.46706 (sp. gr., 1 extracted core) + 1.37330 (1/age) — 0.00190 (d.b.h.)	0.72	0.52	0.019
Y = 0.22646 + 0.52940 (sp. gr., 2 extracted cores) + 1.39142 (1/age) — 0.00176 (d.b.h.)	0.72	0.52	0.019
Y = 0.22343 + 0.47546 (sp. gr., 1 extracted core) + 2.04752 (1/age)	0.71	0.50	0.019
Y = 0.19438 + 0.54067 (sp. gr., 2 extracted cores) + 2.01173 (1/age)	0.71	0.50	0.019
Y = 0.25347 + 0.46750 (weighted sp. gr., 1 extracted core)	0.69	0.48	0.020
Y = 0.34288 + 0.32967 (sp. gr., outer 1/3 of 1 extracted core) — 0.00037 (total height) — 0.00147 (d.b.h.)	0.69	0.48	0.020
Y = 0.25160 + 0.46846 (sp. gr., outer 2/3 of 1 extracted core)	0.69	0.48	0.020
Y = 0.29715 + 0.35858 (sp. gr., outer 1/3 of 2 extracted cores)	0.69	0.48	0.020
Y = 0.35402 + 0.28121 (sp. gr., outer 1/3 of 1 extracted core) — 0.00220 (d.b.h.)	0.68	0.46	0.020
Y = 0.33574 + 0.29749 (sp. gr., outer 1/3 of 2 cores) — 0.00180 (d.b.h.)	0.68	0.46	0.020
Y = 0.32199 + 0.31518 (sp. gr., outer 1/3 of 2 cores) + 0.00016 (age) — 0.00235 (d.b.h.)	0.68	0.46	0.020
Y = 0.34723 + 0.33793 (weighted sp. gr., 2 cores) + 0.00138 (merch. vol.) — 0.00621 (d.b.h.)	0.67	0.45	0.020
Y = 0.30443 + 0.32583 (sp. gr., outer 1/3 of 2 cores)	0.66	0.44	0.020
Y = 0.33987 + 0.28671 (weighted sp. gr., 1 core) + 0.01294 (total height/age) — 0.00253 (d.b.h.)	0.65	0.42	0.021
Y = 0.31360 + 0.36538 (weighted sp. gr., 2 cores) — 0.00265 (d.b.h.)	0.65	0.42	0.021
Y = 0.32003 + 0.30820 (sp. gr., outer 1/3 of 1 extracted core)	0.65	0.42	0.021
Y = 0.36071 + 0.32309 (sp. gr., outer 2/3 of 2 cores) + 0.00184 (merch. vol.) — 0.00735 (d.b.h.)	0.65	0.42	0.021
Y = 0.36498 + 0.24571 (sp. gr., outer 1/3 of 1 core) — 0.00225 (d.b.h.)	0.64	0.41	0.021
Y = 0.35721 + 0.25529 (sp. gr., outer 1/3 of 1 core) + 0.00010 (age) — 0.00261 (d.b.h.)	0.64	0.41	0.021
Y = 0.24932 + 0.49097 (sp. gr., 1 extracted core)	0.63	0.40	0.021
Y = 0.21774 + 0.56059 (sp. gr., 2 extracted cores)	0.63	0.40	0.021
Y = 0.33857 + 0.31712 (weighted sp. gr., 1 core) — 0.00281 (d.b.h.)	0.63	0.40	0.021
Y = 0.34767 + 0.26054 (sp. gr., outer 2/3 of 1 core) + 0.01717 (total height/age) — 0.00241 (d.b.h.)	0.63	0.40	0.021
Y = 0.32211 + 0.34741 (sp. gr., outer 2/3 of 2 cores) — 0.00266 (d.b.h.)	0.62	0.38	0.021
Y = 0.32975 + 0.27297 (sp. gr., outer 1/3 of 1 core)	0.61	0.37	0.022
Y = 0.27065 + 0.40080 (weighted sp. gr., 2 cores)	0.60	0.36	0.022
Y = 0.37028 + 0.22436 (sp. gr., 1 core) + 0.01988 (total height/age) — 0.00306 (d.b.h.)	0.60	0.36	0.022
Y = 0.36517 + 0.23046 (sp. gr., 2 cores) + 0.02142 (total height/age) — 0.00303 (d.b.h.)	0.60	0.36	0.022
Y = 0.35108 + 0.29046 (sp. gr., outer 2/3 of 1 core) — 0.00282 (d.b.h.)	0.59	0.35	0.022
Y = 0.29629 + 0.34787 (weighted sp. gr., 1 core)	0.57	0.32	0.022
Y = 0.38004 + 0.24907 (sp. gr., 1 core) — 0.00363 (d.b.h.)	0.56	0.31	0.023
Y = 0.27765 + 0.38591 (sp. gr., outer 2/3 of 2 cores)	0.56	0.31	0.022
Y = 0.37842 + 0.25119 (sp. gr., 2 cores) — 0.00364 (d.b.h.)	0.55	0.30	0.023
Y = 0.30745 + 0.32388 (sp. gr., outer 2/3 of 1 core)	0.53	0.28	0.023
Y = 0.34114 + 0.25575 (sp. gr., 1 core)	0.43	0.18	0.024
Y = 0.33950 + 0.25749 (sp. gr., 2 cores)	0.42	0.18	0.025

Table 8.—*Mean and standard deviation of the dependent and independent variables used to develop regression equations for the increment core/tree specific gravity relationships for pitch pine*

Variables	Mean	Standard deviation
Dependent		
Weighted tree specific gravity	0.461	0.027
Independent		
D.b.h.	9.869	2.657
Total height	49.150	11.494
Age	67.540	18.163
Merchantable volume	10.472	7.309
D.b.h./age	0.150	0.036
1/age	0.016	0.004
Merchantable volume/age	0.153	0.101
Total height/age	0.790	0.323
Specific gravity, 1 core	0.467	0.045
Specific gravity, outer 2/3 of 1 core	0.473	0.044
Specific gravity, outer 1/3 of 1 core	0.479	0.060
Specific gravity, 2 cores	0.470	0.044
Specific gravity, outer 2/3 of 2 cores	0.474	0.039
Specific gravity, outer 1/3 of 2 cores	0.479	0.054
Weighted specific gravity, 1 core	0.472	0.044
Weighted specific gravity, 2 cores	0.474	0.040
Specific gravity, 1 extracted core	0.430	0.034
Specific gravity, outer 2/3 of 1 extracted core	0.446	0.040
Specific gravity, outer 1/3 of 1 extracted core	0.456	0.057
Specific gravity, 2 extracted cores	0.433	0.030
Specific gravity, outer 2/3 of 2 extracted cores	0.448	0.034
Specific gravity, outer 1/3 of 2 extracted cores	0.456	0.052
Weighted specific gravity, 1 extracted core	0.443	0.040
Weighted specific gravity, 2 extracted cores	0.445	0.035

Saucier, Joseph R., and Clark, Alexander III
1970. Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States. Part IV--Pitch Pine (Pinus rigida Mill.). Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-63, 16 pp.

Specific gravity was determined for pitch pine (Pinus rigida Mill.) in an extracted and unextracted condition from 2,000 trees sampled at 100 locations over its entire range. The average specific gravity of unextracted increment cores was .474, while the extracted increment core specific gravity was .435, a difference of 9 percent. Increment core/tree specific gravity relationships were examined, and equations were developed for predicting tree specific gravity from increment cores. The average tree specific gravity of the species was estimated to be .471. Geographic variation in unextracted and extracted increment core specific gravity was examined. The average extracted increment core specific gravity of trees sampled in New England and New York was significantly lower than the average extracted increment core specific gravity of trees sampled in the remainder of the species range.

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Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part V--Virginia Pine
(*Pinus virginiana* Mill.)

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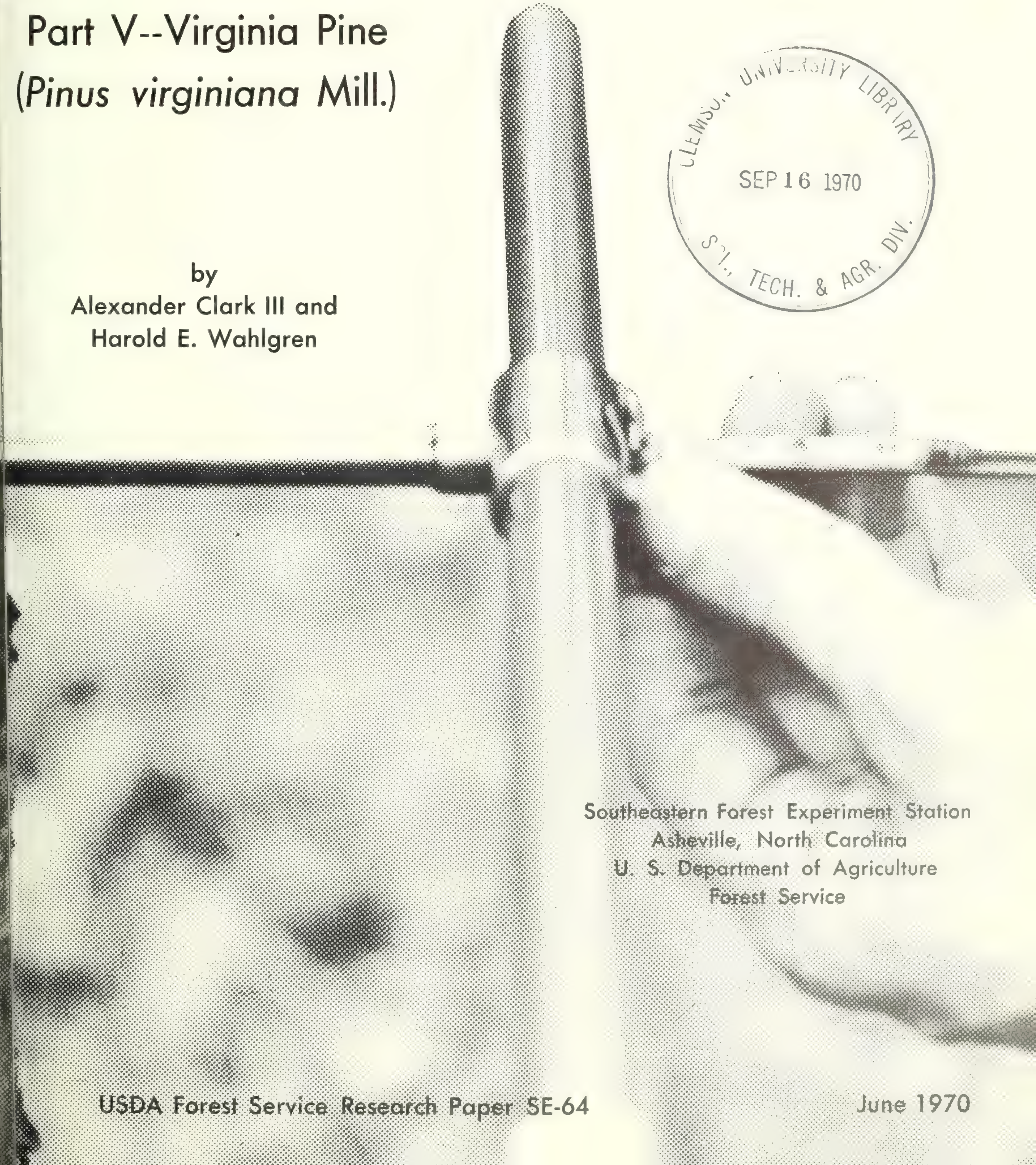
by
Alexander Clark III and
Harold E. Wahlgren



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Forest Service

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Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part V--Virginia Pine (Pinus virginiana Mill.)

by

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INTRODUCTION

This report is the fifth in a series covering the wood density surveys of the minor species of yellow pine in the Eastern United States.[1] Literature review and historical information regarding these surveys were presented in "Part I—Spruce Pine (*Pinus glabra* Walt.)" by Taras and Saucier (1968) and will not be repeated here.

The objectives of the survey were:

(1) To obtain data that will provide an estimate of the average specific gravity of unextracted wood of each minor species, and establish the degree of variation about each mean.

(2) To evaluate increment core/tree specific gravity relationships and develop regression equations for predicting tree specific gravity from increment core specific gravity.

(3) To examine the geographic trends of wood specific gravity within the range of each species, from east to west and from north to south.

MATERIALS AND METHODS

Species

Virginia pine (*Pinus virginiana* Mill.) grows throughout the northern Piedmont and foothills of the Appalachian Mountains from central Pennsylvania southwestward to northeastern Mississippi, Alabama, and northern Georgia (fig. 1). The species is also found as far north as Long Island, New York, and in scattered areas of Ohio and southern Indiana. Virginia pine is also known as scrub pine, Jersey pine, spruce pine, and poverty pine. It was considered a "forest weed tree" 60 years ago, but with increasing demands for wood its value as a commercial species has improved.

Virginia pine is intolerant of shade and usually grows in pure stands as a pioneer species. It is found on the poorest of heavy, dry soils on abandoned farmland where much of the A horizon has been eroded away. It is also found in mixed stands growing with shortleaf, pitch, Table-Mountain, loblolly, and white pines, and with various oaks, red maple, hickories, blackgum, and sweetgum (Fowells 1965, pp. 471-477). It is susceptible to windthrow because of its shallow root system and is easily damaged by fire because of its thin bark (Slocum and Miller 1953).

Virginia pine is small to medium in size, reaching 40 to 60 feet in height with d.b.h.

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[1] This study was conducted in cooperation with the Forest Products Laboratory, the Northeastern Forest Experiment Station, the Southern Forest Experiment Station, state forestry services, the pulp and paper industries, the southern pine plywood and sawmill industries, and numerous private forest owners throughout the Southern and Eastern United States.

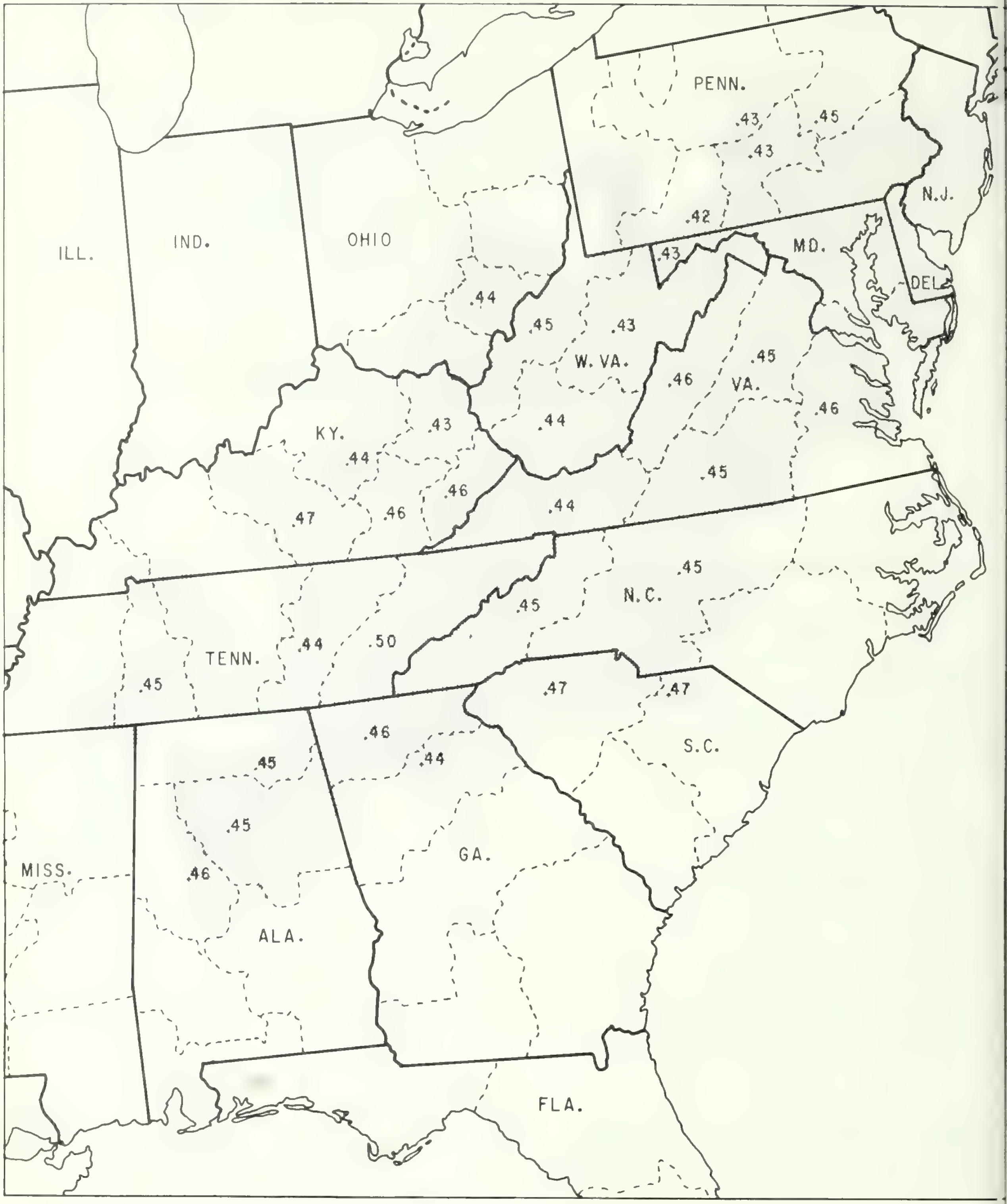

Figure 1.—*The natural range of Virginia pine. Numbers indicate average unextracted increment core specific gravity by Forest Survey Units.*

ranging up to 20 inches (fig. 2A). The largest diameter recorded for the species is 30.8 inches and the greatest height is 105 feet (Slocum and Miller 1953). Young Virginia pines are characterized by crowns that appear narrow and spruce-like with persistent dead branches; the crowns of mature trees are short and sparsely foliated with numerous persistent cones (Harlow and Harrar 1950).

The needles of Virginia pine are about 2 inches long, yellow-green, stout, usually twisted, and grow in fascicles of two (fig. 2B). The cones are 2 and 3 inches long (resembling those of shortleaf pine), but after opening, they are flatter based and persist for several years. Cone scales are thin, flat, and terminate in a sharp prickle (fig. 2C). The bark on young stems is thin and smooth, eventually becoming plated with thin, dark, red-brown scales (fig. 2D).

Field Sampling Procedure

Crews collected cores from Virginia pine while conducting routine Forest Survey inventories in Alabama, Georgia, South Carolina, North Carolina, and Virginia. In Georgia and North Carolina, every fifth forest inventory plot was a specific gravity sample plot. In Virginia and South Carolina, specific gravity data were collected from 10 percent of the regular Forest Survey inventory plots. In Alabama, sample plots were located on a 12- by 12-mile grid.

The trees sampled at each plot were selected with frequency proportional to basal area. A basal area factor of 10 square feet per acre was used in Georgia and North Carolina; a factor of 37.5 square feet per acre was used in Alabama, South Carolina, and Virginia. A single increment core was taken at breast height from each tree.

In order to sample Virginia pine over its entire range, a supplemental survey was made over the remainder of the range by personnel from the Forestry Sciences Laboratory, Athens, Georgia.

Forty plots were randomly selected, with the probability proportional to the commercial forest area within Forest Survey Units[2] containing Virginia pine. A 6-mile grid system was used to locate plots randomly within survey units. At each plot location, a random azimuth was selected along which the first 30 trees, over 5.0 inches d.b.h. and showing no signs of heartrot, were sampled by removing two increment cores from opposite sides of each tree. Total height, merchantable height to a 4-inch top, and d.b.h. of each sample tree were recorded.

The trees to be used for analyzing increment core/tree specific gravity relationships were selected at 10 locations within the range of Virginia pine. Two increment cores were taken from each of at least 24 trees at each location before they were felled. Beginning at the butt end of the tree, 1-inch-thick disks were cut at 5-foot intervals to a 4-inch top. Total height and merchantable height to a 4-inch top were recorded, along with diameter of each disk.

Laboratory Procedures

The specific gravity of all unextracted and extracted increment cores was determined with the maximum moisture method described by Smith (1954). The specific gravity of the wood disks was determined by the buoyancy method (Heinrichs 1954) and is based on green volume and ovendry weight.

Increment cores from all trees sampled in the supplemental survey were extracted after unextracted specific gravity was determined. These extractions were made with a mixture of two parts benzene and one part ethyl alcohol for 24 hours. No wood disks were extracted.

The average specific gravity of the individual 5-foot bolts within each tree was computed as the mean of the bolt's terminal disks. The average specific gravity of the tree was determined by weighting the average bolt specific gravity by bolt volume. Formulas for all these computations are shown in the Appendix. A discussion of the analysis of the increment core/tree specific gravity relationship data is presented in an office report available from the Forestry Sciences Laboratory, Carlton Street, Athens, Georgia 30601.

RESULTS AND DISCUSSION

Virginia Pine Specific Gravity and Its Variation

The average specific gravity of unextracted Virginia pine increment cores was .449, based on the average of one whole

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[2] Forest Survey Units are subdivisions of a state based in part on county boundaries and in part on physiography of the state. They are established for the purpose of sampling and reporting results efficiently.

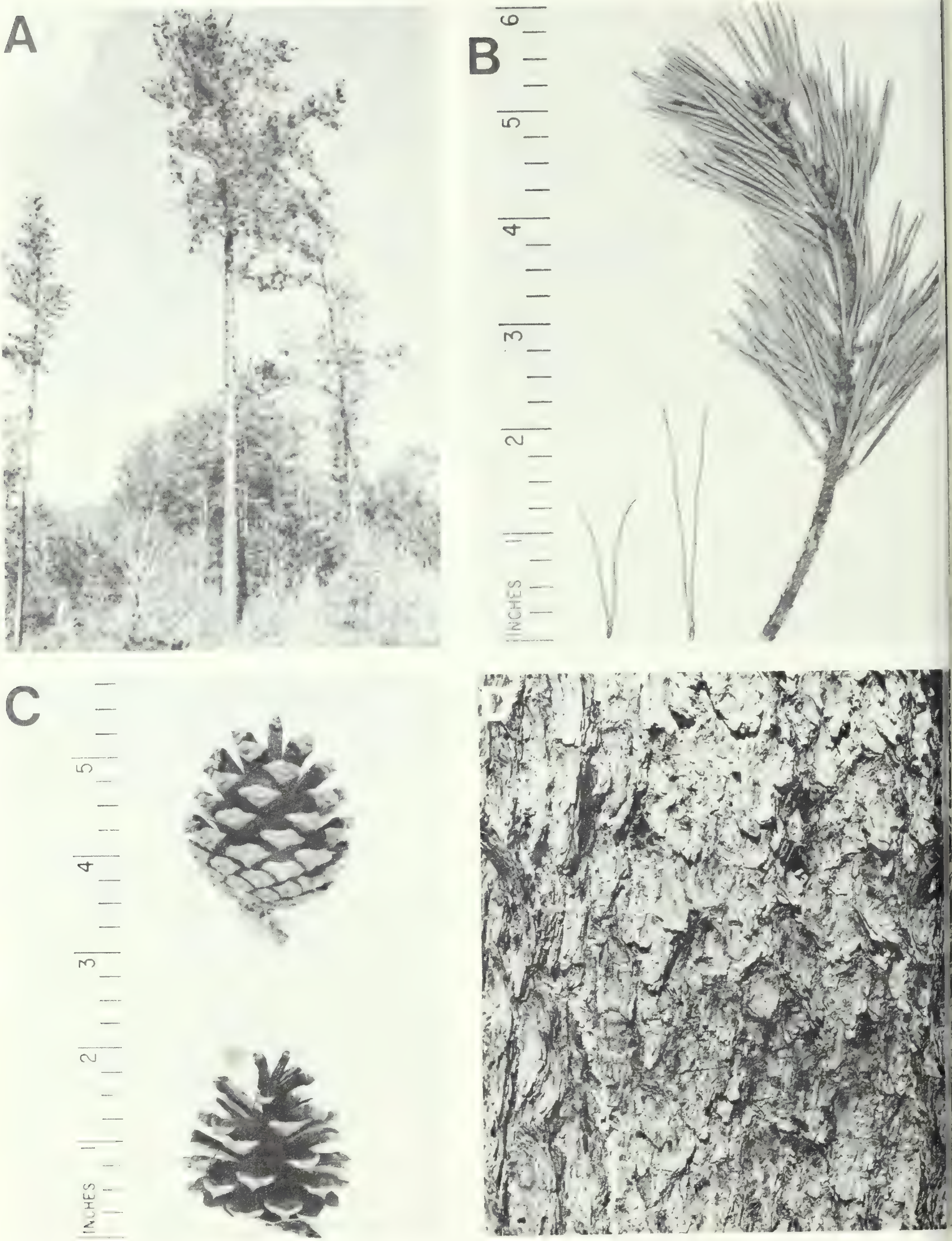

Figure 2.—*Botanical features of Virginia pine:* (*A*) *mature tree,* (*B*) *needles,* (*C*) *open and partially open cones,* (*D*) *bark.*

increment core from 2,114 trees collected over the range of the species. The standard error of the mean increment core specific gravity was .009, and the standard deviation of the individual observations about the mean was .055. The average tree sampled was 8.1 inches d.b.h. and 32 years old.

The estimated average tree specific gravity for Virginia pine was obtained by using the following regression equation:

$$\text{Tree specific gravity } (Y) = 0.19442 + 0.56175(\text{sp. gr., 1 unextracted core}) \quad (1)$$

When the specific gravity of all the trees sampled was adjusted to tree specific gravity using equation (1), the average tree specific gravity was .447, with a standard deviation from regression of .004.

The specific gravity of unextracted increment cores and the estimated tree specific gravity by three diameter classes (4.0 to 8.9 inches; 9.0 to 14.9 inches; and 15.0+ inches) are presented in table 1 for each Forest Survey Unit sampled.

The average unextracted increment core specific gravity is shown in figure 1 to illustrate specific gravity changes with geographic location. There appear to be no east-west or north-south trends in increment core specific gravity. The relative uniformity of Virginia pine specific gravity over its entire range may be associated with the restricted site conditions where it grows.

Table 1.—*Specific gravity data for Virginia pine by states and by Forest Survey Units within states*

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Mean diameter of sampled trees	Mean age of sampled trees	Increment core specific gravity		Estimated tree specific gravity[1] mean and standard error	Approximate timber volume[2]
						Mean and standard error	Standard deviation		
Alabama	*Number*	*Inches*	*Number*	*Inches*	*Years*				*Million cu. ft.*
West-central (4)	3	4.0-8.9	9	6.3	25	.452 (.010)	.027	.448 (.006)	16.3
		9.0-14.9	1	11.0	48	.560 (----)	...	.509 (----)	11.7
		15.0+	0	----	----	----	----	----	----
North-central (5)	5	4.0-8.9	19	6.8	20	.444 (.005)	.052	.444 (.004)	70.4
		9.0-14.9	3	10.5	31	.483 (.038)	.065	.466 (.010)	58.0
		15.0+	0	----	----	----	----	----	----
North (6)	1	4.0-8.9	6	6.5	22	.452 (.018)	.044	.448 (.007)	21.3
		9.0-14.9	3	12.4	52	.457 (.024)	.041	.451 (.010)	12.3
		15.0+	0	----	----	----	----	----	----
State total	9	4.0-8.9	34	6.6	21	.448 (.008)	.047	.446 (.003)	108.0
		9.0-14.9	7	11.4	42	.483 (.018)	.048	.466 (.010)	82.0
		15.0+	0	----	----	----	----	----	----
Georgia									
North-central (4)	2	4.0-8.9	2	6.6	16	.430 (.040)	.071	.436 (.012)	6.3
		9.0-14.9	1	9.6	23	.460 (----)	----	.453 (----)	9.5
		15.0+	0	----	----	----	----	----	----
North (5)	15	4.0-8.9	31	6.5	21	.448 (.012)	.047	.446 (.003)	90.8
		9.0-14.9	13	11.9	46	.488 (.011)	.042	.468 (.005)	73.0
		15.0+	1	21.6	58	.470 (----)	----	.458 (----)	8.3
State total	17	4.0-8.9	33	6.5	21	.447 (.012)	.047	.445 (.003)	97.1
		9.0-14.9	14	11.8	44	.486 (.010)	.041	.467 (.005)	82.5
		15.0+	1	21.6	58	.470 (----)	----	.458 (----)	8.3
Kentucky									
Northern Cumberland (1)	3	4.0-8.9	74	6.9	24	.434 (.006)	.033	.438 (.002)	----
		9.0-14.9	16	9.9	29	.435 (.008)	.031	.439 (.004)	----
		15.0+	0	----	----	----	----	----	----
Eastern (2)	1	4.0-8.9	25	6.4	26	.460 (.006)	.031	.453 (.003)	----
		9.0-14.9	5	10.6	28	.494 (.025)	.056	.472 (.008)	
		15.0+	0	----	----	----	----	----	----
Blue Grass (3)	1	4.0-8.9	24	7.2	21	.440 (.007)	.036	.441 (.003)	----
		9.0-14.9	6	10.2	22	.432 (.008)	.020	.437 (.007)	----
		15.0+	0	----	----	----	----	----	----

Table 1.—*Specific gravity data for Virginia pine by states and by Forest Survey Units within stat (continued)*

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Mean diameter of sampled trees	Mean age of sampled trees	Increment core specific gravity		Estimated tree specific gravity[1] mean and standard error	Appro imat timbe volum
						Mean and standard error	Standard deviation		
	Number	*Inches*	*Number*	*Inches*	*Years*				*Millio cu. ft*
Kentucky (continued)									
Southern Cumberland (4)	3	4.0-8.9	65	7.2	30	.457 (.009)	.036	.451 (.002)	----
		9.0-14.9	25	10.0	32	.452 (.002)	.026	.448 (.003)	----
		15.0+	0	----	----	----	----	----	----
Pennyroyal (5)	2	4.0-8.9	24	6.9	34	.464 (.015)	.034	.455 (.003)	----
		9.0-14.9	36	10.7	38	.479 (.014)	.034	.463 (.003)	----
		15.0+	0	----	----	----	----	----	----
State total	10	4.0-8.9	212	7.0	27	.448 (.002)	.031	.446 (.001)	-
		9.0-14.9	88	10.3	33	.461 (.009)	.040	.453 (.002)	----
		15.0+	0	----	----	----	----	----	----
Maryland									
Western (2)	4	4.0-8.9	77	7.5	45	.434 (.009)	.033	.438 (.002)	----
		9.0-14.9	43	10.3	43	.432 (.007)	.032	.437 (.003)	----
		15.0+	0	----		----	----	----	----
North Carolina									
Piedmont (3)	22	4.0-8.9	115	6.4	20	.445 (.005)	.032	.444 (.002)	----
		9.0-14.9	48	10.6	31	.470 (.011)	.074	.458 (.002)	----
		15.0+	9	16.3	43	.479 (.011)	.037	.463 (.001)	----
Mountain (4)	8	4.0-8.9	32	6.7	20	.440 (.010)	.039	.441 (.003)	94.3
		9.0-14.9	14	11.4	31	.454 (.017)	.050	.449 (.005)	88.3
		15.0+	1	17.4	55	.530 ( )		.492 (.017)	5.4
State total	30	4.0-8.9	147	6.5	20	.444 (.002)	.032	.444 (.001)	317.8
		9.0-14.9	62	10.8	31	.467 (.004)	.078	.457 (.002)	265.8
		15.0+	10	16.4	44	.484 (.005)	.036	.466 (.005)	25.4
Ohio									
Southeastern (2)	1	4.0-8.9	22	6.9	26	.436 (.009)	.042	.439 (.005)	----
		9.0-14.9	8	9.7	28	.439 (.014)	.039	.441 (.006)	----
		15.0+	0	----	----	----	----	----	----
Pennsylvania									
Southwestern (4)	1	4.0-8.9	27	6.3	33	.420 (.006)	.033	.430 (.003)	.
		9.0-14.9	3	9.3	39	.417 (.017)	.030	.429 (.010)	----
		15.0+	0	----	----	----	----	----	----
North-central (5)	1	4.0-8.9	23	7.6	51	.438 (.007)	.034	.440 (.004)	----
		9.0-14.9	7	10.0	54	.417 (.014)	.037	.429 (.006)	----
		15.0+	0	----	----	----	----	----	----
South-central (6)	2	4.0-8.9	36	7.1	46	.423 (.001)	.042	.432 (.003)	----
		9.0-14.9	24	11.1	50	.441 (.007)	.034	.442 (.003)	----
		15.0+	0	----		----	----	----	----
Northeastern (7)	1	4.0-8.9	14	7.2	54	.450 (.009)	.032	.447 (.005)	----
		9.0-14.9	16	10.2	62	.447 (.010)	.040	.445 (.004)	----
		15.0+	0	----	----	----	----	----	----
State total	5	4.0-8.9	100	7.0	45	.430 (.006)	.032	.436 (.002)	----
		9.0-14.9	50	10.8	54	.438 (.006)	.033	.440 (.002)	----
		15.0+	0	--	----	----	----	----	----
South Carolina									
Northern Coastal Plain (2)	1	4.0-8.9	2	7.2	26	.470 (.012)	.018	.458 (.012)	----
		9.0-14.9	0	--	-	----	- -	----	----
		15.0+	0	----	----	----	- -	----	----
Piedmont (3)	8	4.0-8.9	13	7.4	22	.456 (.011)	.033	.451 (.005)	----
		9.0-14.9	20	10.9	30	.474 (.005)	.054	.461 (.004)	----
		15.0+	1	21.6	44	.530 (----)	--	.492 (.017)	- -
State total	9	4.0-8.9	15	7.4	23	.458 (.010)	.032	.452 (.004)	----
		9.0-14.9	20	10.9	30	.474 (.005)	.054	.461 (.004)	----
		15.0+	1	21.6	44	.530 (----)	...	.492 (.017)	----

Table 1.—*Specific gravity data for Virginia pine by states and by Forest Survey Units within states (continued)*

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Mean diameter of sampled trees	Mean age of sampled trees	Increment core specific gravity		Estimated tree specific gravity[1] mean and standard error	Approximate timber volume[2]
						Mean and standard error	Standard deviation		
	Number	*Inches*	*Number*	*Inches*	*Years*				*Million cu. ft.*
Tennessee									
West-central (2)	2	4.0-8.9	49	7.0	22	.444 (.013)	.032	.444 (.002)	. .
		9.0-14.9	9	9.4	23	.467 (.005)	.027	.457 (.006)	....
		15.0+	2	17.6	43	.515 (.006)	.009	.484 (.012)	. .
Plateau (4)	3	4.0-8.9	64	6.8	26	.443 (.002)	.029	.443 (.002)	
		9.0-14.9	26	9.9	29	.447 (.009)	.036	.445 (.003)	
		15.0+	0	----	- -	- --		----	----
Eastern (5)	2	4.0-8.9	33	7.6	40	.498 (.012)	.024	.474 (.003)	...
		9.0-14.9	26	10.7	44	.508 (.019)	.043	.480 (.003)	..
		15.0+	1	15.4	34	.480 (----)	----	.464 (.017)	----
State total	7	4.0-8.9	146	7.1	28	.456 (.010)	.030	.450 (.017)	....
		9.0-14.9	61	10.2	35	.476 (.018)	.053	.462 (.002)	....
		15.0+	3	16.8	40	.503 (.011)	.024	.477 (.010)	....
Virginia									
Coastal Plain (1)	13	4.0-8.9	55	6.9	28	.459 (.010)	.044	.452 (.002)	109.2
		9.0-14.9	34	10.9	41	.470 (.005)	.044	.458 (.003)	110.8
		15.0+	4	16.0	51	.468 (.005)	.019	.457 (.008)	7.2
Southern Piedmont (2)	14	4.0-8.9	137	6.7	23	.443 (.005)	.053	.443 (.001)	290.4
		9.0-14.9	54	10.6	34	.466 (.009)	.060	.456 (.002)	190.7
		15.0+	4	16.6	49	.457 (.012)	.039	.451 (.008)	9.9
Northern Piedmont (3)	15	4.0-8.9	114	6.7	23	.446 (.005)	.032	.445 (.002)	206.4
		9.0-14.9	52	11.0	33	.456 (.006)	.044	.450 (.002)	159.8
		15.0+	0	----	----	—	----	---	- -
Northern Mountain (4)	11	4.0-8.9	60	6.6	33	.462 (.007)	.053	.454 (.002)	74.1
		9.0-14.9	20	11.7	55	.475 (.006)	.040	.461 (.004)	44.7
		15.0+	0	----	----	----	----	----	----
Southern Mountain (5)	7	4.0-8.9	26	6.9	21	.430 (.011)	.038	.436 (.003)	34.9
		9.0-14.9	10	10.0	23	.452 (.010)	.046	.448 (.005)	25.6
		15.0+	0	----	----	----	----	----	----
State total	60	4.0-8.9	392	6.7	25	.448 (.001)	.046	.446 (.001)	715.0
		9.0-14.9	170	10.9	37	.464 (.001)	.049	.455 (.001)	531.6
		15.0+	8	16.3	50	.462 (.007)	.028	.454 (.006)	17.1
West Virginia									
Northwestern (1)	4	4.0-8.9	98	6.6	30	.443 (.008)	.053	.443 (.002)	...
		9.0-14.9	22	10.2	59	.476 (.019)	.053	.462 (.004)	....
		15.0+	0	----	- --	----	- --	----	...
Northeastern (2)	4	4.0-8.9	82	7.2	34	.433 (.004)	.033	.438 (.002)	--
		9.0-14.9	36	10.8	40	.439 (.007)	.029	.441 (.003)	. .
		15.0+	2	15.1	40	.420 (.051)	.012	.430 (.012)	....
Southern (3)	5	4.0-8.9	117	6.6	31	.442 (.005)	.070	.443 (.002)	--
		9.0-14.9	32	10.9	50	.448 (.013)	.049	.446 (.003)	....
		15.0+	1	15.2	60	.440 (----)	....	.441 (.017)	. .
State total	13	4.0-8.9	297	6.7	32	.440 (.002)	.063	.441 (.001)	
		9.0-14.9	90	10.7	47	.451 (.005)	.047	.448 (.002)	
		15.0+	3	15.1	47	.427 (.005)	.012	.434 (.010)	....
All States	166	4.0-8.9	1,475	6.8	29	.445 (.009)	.055	.444 (.001)	....
		9.0-14.9	613	10.7	39	.460 (.009)	.055	.453 (.001)	
		15.0+	26	16.7	46	.474 (.006)	.033	.461 (.003)	...
Total (all classes)	166		2,114	8.1	32	.449 (.009)	.055	.447 (.004)	. .

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[1] Estimates were made with equation (1):

$Y = 0.19442 + 0.56175$ (sp. gr., 1 unextracted core).

[2] From Forest Survey data of the Southern and Southeastern Forest Experiment Stations.

Increment Core/Tree Specific Gravity Relationships—Simple Linear and Multiple Regression Analyses

A discussion of the increment core/tree specific gravity relationships is given in an office report available upon request and will not be treated in detail here.

The increment core/tree specific gravity relationships examined by simple linear regressions are listed in table 2 for each plot sampled and for all sample plots combined. Also included in table 2 are the correlation coefficients and standard deviations from regressions.

Solvent extraction of the increment cores resulted in a 2-percent decrease in the coefficient of determination. Thus, there appears to be no reason for extracting Virginia pine increment cores to improve ability to predict tree specific gravity.

A stepwise multiple regression analysis was made to determine if the addition of d.b.h., age, total height, d.b.h./age, volume/age, 1/age, and total height/age would provide a higher coefficient of determination than that obtained with the simple regressions. None of the tree characteristics considered gave significant improvement in the relationship between one unextracted increment core and tree specific gravity.

Equation (1), a simple linear equation, was associated with 64 percent of the variation about regression and had a standard deviation from regression of .017. The best multiple regression equation had the re ciprocal of age as the second variable, bu the addition of this variable increased th coefficient of determination by only 1 per cent over that for the simple linear regres sion using one extracted core to estimat tree specific gravity.

Relationship of Unextracted and Extracted Core Specific Gravity

The specific gravity of increment core collected from trees in the western and northern parts of the species range wer determined in both the unextracted and ex tracted condition. The average unextracted increment core specific gravity based on 1,200 increment cores was .451 and the extracted increment core specific grav ity was .421, a decrease of 7.1 percent (based on the extracted core specific gravity value) From these data, a regression equation fo predicting extracted core specific gravity from unextracted core specific gravity wa developed. Equation (2) has a correlation coefficient of .86 and a standard deviation from regression of .015.

$$Y = 0.10315 + 0.70493\ X_1 \qquad (2$$

Where: Y = specific gravity of one ex tracted increment core

X_1 = specific gravity of one un extracted increment core

Similar high correlations have been reported for the other minor species of southern yellow pine (Taras and Saucier 1968; Clark and Saucier 1969).

Table 2.—*Increment core specific gravity means, standard deviations, simple linear regression equa tions, coefficients of determination, and standard deviations from regressions for increment core tree specific gravity relationships for each plot sampled and all plots combined*

County and state	Trees sampled	Increment core specific gravity mean and standard deviation	Regression equation	r	Standard deviation from regression
	Number				
Lawrence, Ala.	27	.469 (.033)	$Y = 0.20710 + 0.53266\ X_1$	.78	.014
Caldwell, N. C.	37	.482 (.033)	$Y = 0.18431 + 0.58561\ X_1$	.84	.013
Person, N. C.	24	.453 (.036)	$Y = 0.23283 + 0.47833\ X_1$	.68	.019
Washington, Ohio	25	.429 (.034)	$Y = 0.11185 + 0.74829\ X_1$	.87	.014
Bedford, Pa.	25	.489 (.057)	$Y = 0.32213 + 0.31491\ X_1$	.71	.018
McMinn, Tenn.	26	.485 (.032)	$Y = 0.24331 + 0.47386\ X_1$	.68	.017
Henry, Va.	33	.448 (.036)	$Y = 0.14820 + 0.66162\ X_1$	.90	.012
Prince Edward, Va.	36	.462 (.027)	$Y = 0.18786 + 0.58130\ X_1$	.71	.016
Albemarle, Va.	32	.445 (.032)	$Y = 0.17692 + 0.58179\ X_1$	.73	.018
Pocahontas, W. Va.	25	.448 (.036)	$Y = 0.25223 + 0.42924\ X_1$	.60	.021
All areas combined	290	.461 (.040)	$Y = 0.19442 + 0.56175\ X_1$	.80	.017

SUMMARY AND CONCLUSIONS

The average specific gravity of Virginia pine increment cores taken at d.b.h. was .449, based on one whole increment core from 2,114 trees collected over the range of the species. The average tree specific gravity of the species was estimated to be .447. There appear to be no distinct north-south or east-west geographic trends in specific gravity within the range of the species.

The best equation developed for predicting Virginia pine tree specific gravity was equation (1), in which the specific gravity of one unextracted increment core was the independent variable. Extracting a single core did not improve the prediction of tree specific gravity. The addition of a second or third independent variable involving such tree characteristics as d.b.h., age, or total height did not improve the prediction of tree specific gravity from an unextracted core.

Equation (2) was developed for predicting extracted increment core specific gravity from unextracted increment core specific gravity and was associated with 74 percent of the total variation in extracted increment core specific gravity.

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APPENDIX

Computational Procedures

1. Increment core specific gravity $= \dfrac{\text{ovendry weight of core}}{\text{green weight of core} - .3464\,(\text{ovendry weight of core})}$

2. Disk specific gravity $= \dfrac{\text{ovendry weight of disk}}{\text{displaced volume of disk}}$

3. Bolt specific gravity $= \dfrac{\text{specific gravity top disk} + \text{specific gravity bottom disk}}{2}$

4. Tree specific gravity $= \dfrac{\sum\limits_{1-n} (\text{bolt volume} \times \text{bolt specific gravity})}{\sum\limits_{1-n} \text{bolt volumes}}$

5. Bolt volume = bolt length, feet $\times \left[\dfrac{.005454\,(\text{d.i.b.})_t^2 + .005454\,(\text{d.i.b.})_b^2}{2} \right]$

   where: t = top of bolt
   b = base of bolt

6. (a) Mean core specific gravity $\bar{x} = \dfrac{\Sigma_i \Sigma_j X_{ij}}{m_1 n_1}$

   where: X_{ij} = the core specific gravity for the jth tree at the ith location
   m_1 = number of trees at each location
   n_1 = number of locations

   (b) The standard deviation of individuals was estimated from the sample range of the core specific gravitie using the tabular values of the ratio of the standard deviation to the range.

7. Tree specific gravities were estimated from regression by:

   (a) Tree specific gravity $(Y) = b_0 + b_1 X_1$

   where: X_1 = specific gravity of 1 unextracted core

   (b) The standard error of the predicted mean tree specific gravity was estimated by--

$$S_{\hat{y}} = \left[S^2_{y.x} \left(\frac{1}{n} + \frac{(\bar{x}_1 - \bar{x}_2)^2}{\Sigma x_2^2} \right) \right]^{\frac{1}{2}}$$

   where: $S^2_{y.x}$ = residual mean squares
   n = number of trees in large sample
   $\bar{x}_1$ = mean unextracted core specific gravity of large sample
   $\bar{x}_2$ = mean unextracted core specific gravity of small sample

(c) The standard error of the core mean was approximated by the following computation when the variances were pooled to obtain the mean core specific gravity of more than one location:

$$\text{standard error} = \sqrt{\frac{K}{(\Sigma n_i)^2}\left(\frac{\Sigma S_i^2 + \bar{x}^2 \Sigma n_i^2 - 2\bar{x}\Sigma n_i S_i}{K-1}\right)}$$

where: K = the number of locations at which trees were bored for specific gravity

S_i = the sum of specific gravities of cores at the ith location ($= \Sigma_j X_{ij}$)

(d) When variances were not pooled the standard error of the mean was approximated by--

$$\text{standard error} = \frac{S}{\sqrt{n}}$$

where: S = standard deviation estimated from the sample range of core specific gravities

n = number of observations in sample

8. Percentage difference in specific gravity due to extraction $= \frac{\text{unextracted core sp. gr. - extracted core sp. gr.}}{\text{extracted core sp. gr.}} \times 100$

Clark, Alexander III, and Wahlgren, Harold E.
1970. Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States. Part V--Virginia Pine (Pinus virginiana Mill.). Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-64, 11 pp.

Specific gravity was determined for Virginia pine (Pinus virginiana Mill.) from 2,114 trees sampled over the range of the species. The average increment core specific gravity of the species was .449. Increment core/tree specific gravity relationships were examined, and equations for predicting tree specific gravity from increment cores were developed. The average tree specific gravity of the species was estimated to be .447. No geographic trends were detected in the specific gravity of Virginia pine.

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Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part VI--Pond Pine
(*Pinus serotina* Michx.)

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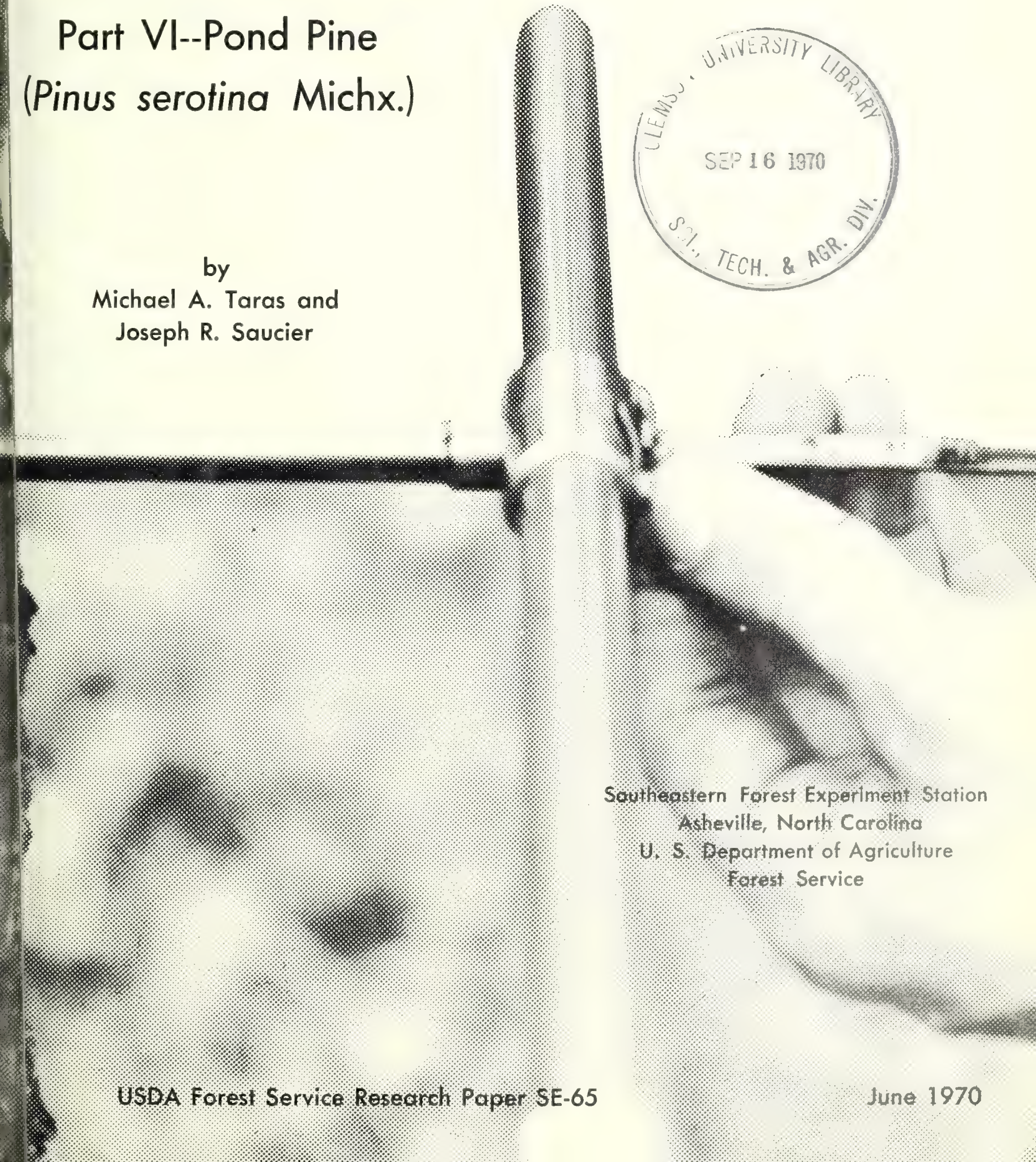
by
Michael A. Taras and
Joseph R. Saucier



Southeastern Forest Experiment Station
Asheville, North Carolina
U. S. Department of Agriculture
Forest Service

USDA Forest Service Research Paper SE-65

June 1970

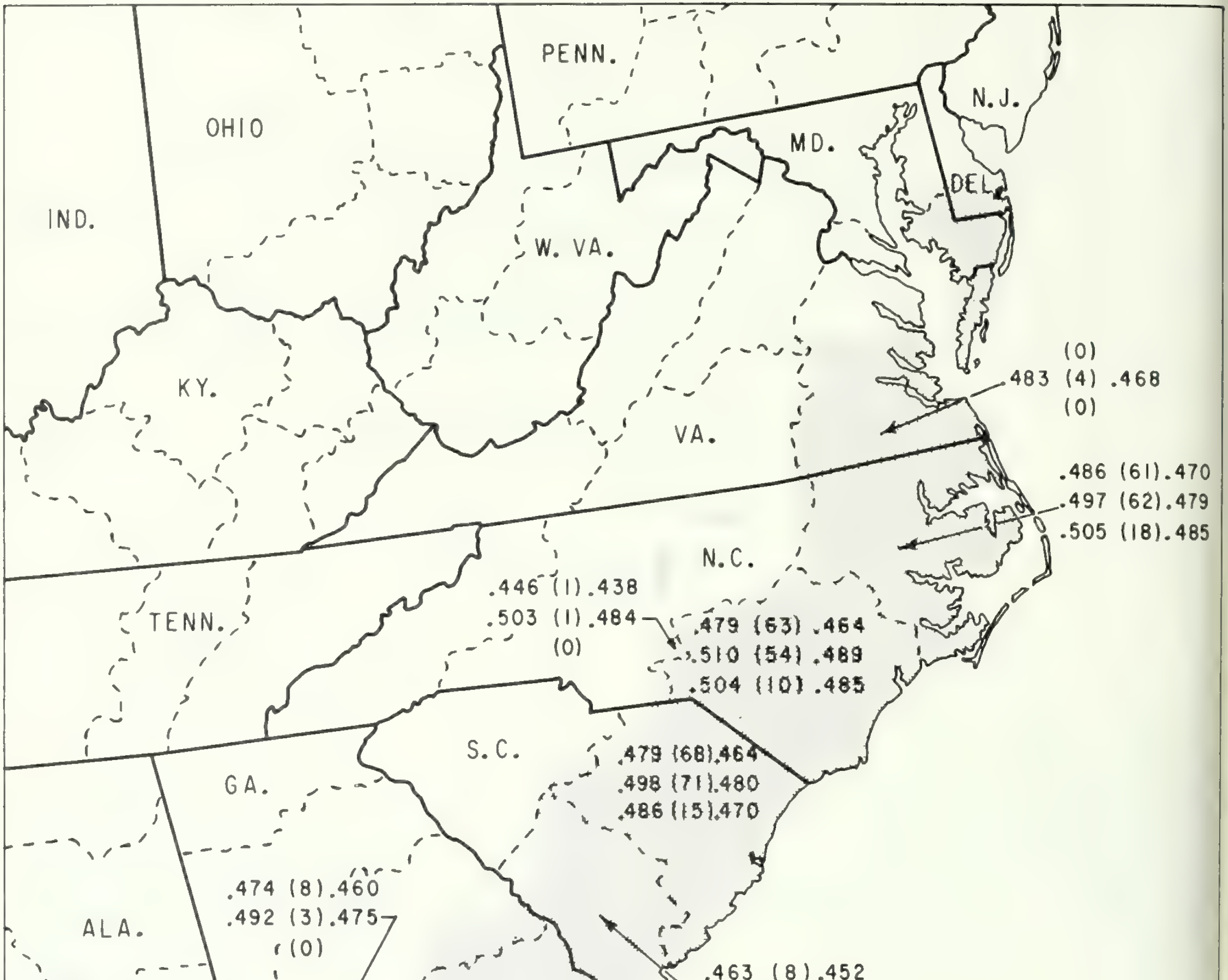


Figure 1.—*The natural range of pond pine. Numbers indicate specific gravity for three diameter classes by Forest Survey Units. The number on the left is the unextracted increment core specific gravity, the number on the right is the predicted tree specific gravity, and the number in parentheses is the sample size.*

of three and rarely four (fig. 2D). This pine is closely allied to pitch pine (Dallimore and Jackson 1967, pp. 484-485) but is distinguishable by its more resinous winter buds and longer leaves.

Estimated timber volume for this species in Florida, Georgia, South Carolina, and North Carolina is 1.5 billion cubic feet.

Field Sampling Procedure

The increment core samples for this species were obtained during regular Forest Survey inventories. One increment core was removed from each sample tree on the side facing plot center. In Florida, Georgia, and North Carolina, trees were sampled for specific gravity on every fifth forest inventory plot. One-point plots were used in these states. Sample trees were selected on each plot with a frequency proportional to a basal area factor of 10 square feet per acre. In Virginia and South Carolina, a 10-point cluster of plots spaced on 1 acre was measured at each sample location using a basal area factor of 37.5 square feet per acre. Since the sampling intensity was approximately three times greater in these two states than in the others, the number of plots sampled for specific gravity was adjusted so that specific gravity was sampled at approximately the same intensity in all states.

Sample trees to be used for analyzing increment core/tree specific gravity relationships were collected at four different locations within the range of the species. There were two plots in North Carolina, one in South Carolina, and one in Florida. Two increment cores were taken from each of 25 trees at each location before they were elled. Beginning at the butt-end of the ree, 1-inch-thick disks were cut at 5-foot ntervals to a 4-inch top. Total height, and merchantable height to a 4-inch top were recorded, along with diameter of each disk.

aboratory Procedures

The specific gravity of all unextracted nd extracted increment cores was determined by the maximum moisture method escribed by Smith (1954). The specific ravity of wood disks was determined by the buoyancy method (Heinrichs 1954) and is based on green volume and ovendry weight.

Increment cores from all trees were extracted after unextracted specific gravity was determined. Extractions were made with a mixture of two parts benzene and one part ethyl alcohol for 24 hours. No wood disks were extracted.

The increment cores from the trees collected to analyze increment core/tree specific gravity relationships were each divided into three equal parts and the specific gravity of each segment was determined. The purpose of this was to obtain a weighted increment core specific gravity and to examine the relationship of parts (1/3 or 2/3) of whole increment cores to total tree specific gravity. Weighted total core specific gravity was determined by weighting the specific gravity of segments by the cross-sectional areas they represented.

The average specific gravity of the individual 5-foot bolts within each tree was computed as the mean of the bolt's terminal disks. The average specific gravity of the tree was determined by weighting the average bolt specific gravity by bolt volume. Formulas for all computations above are shown in the Appendix. A discussion of the analysis of the increment core/tree specific gravity relationship data is presented in an office report available from the Forestry Sciences Laboratory, Carlton Street, Athens, Georgia 30601.

RESULTS AND DISCUSSION

Pond Pine Specific Gravity and Its Variation

The average specific gravity of *unextracted* pond pine increment cores was .492, based on one increment core from 554 sample trees collected over most of the range of the species. The standard error of the mean increment core specific gravity was .001, and the standard deviation of the individual observations about the mean was .049. Based on 180 trees, McElwee and Zobel (1962) reported a mean specific gravity of .52 for pond pine increment cores, a difference of .028 units in specific gravity from the average reported here. This difference is due in part to sampling procedure. McElwee and Zobel determined specific gravity on mature wood only and did not sample the core wood from the central part of the tree.

The average specific gravity of *extracted* increment cores was .454; standard error was .001 and standard deviation of individuals was .035. The average specific gravity of unextracted and extracted incre-

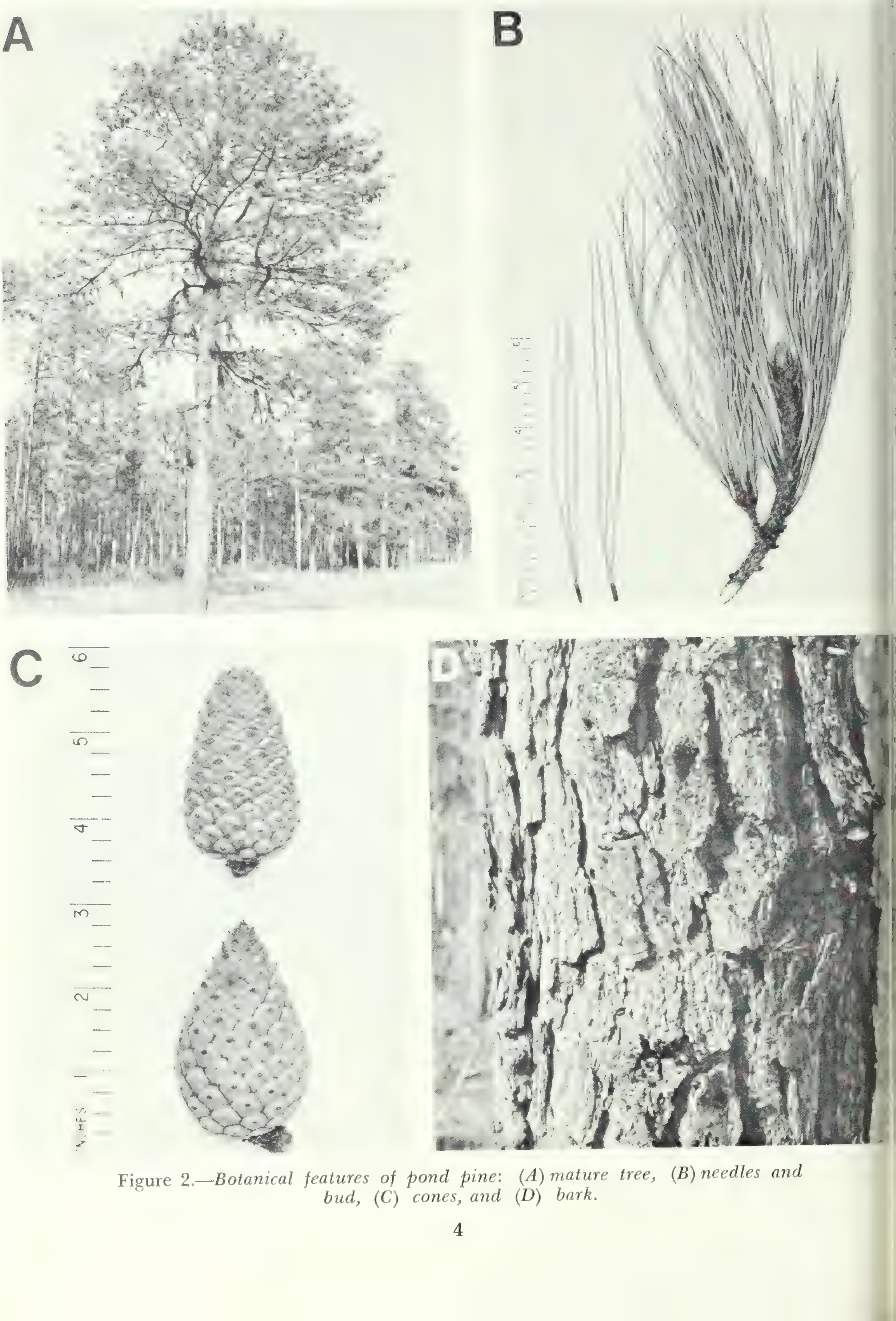


Figure 2.—*Botanical features of pond pine: (A) mature tree, (B) needles and bud, (C) cones, and (D) bark.*

ment cores by counties within each state sampled is shown in table 1, which also includes the average d.b.h., age, and percentage difference in specific gravity resulting from extraction of the increment cores. The mean difference between unextracted and extracted increment core specific gravity was 8.5 percent. This is about 2 percent higher than the 6.5 percent difference reported for loblolly pine by Taras and Saucier (1967), a species which grows in the same general area as pond pine and is often mistaken for it. Pitch pine, which is related taxonomically to pond pine, had an equally high percentage (9 percent) difference between unextracted and extracted specific gravity (Saucier and Clark 1970). The average specific gravity differences between unextracted and extracted increment cores by diameter class were 7.6 percent for he 5.0 to 8.9 inch diameter class; 8.8 perent for the 9.0 to 14.9 inch diameter class; nd 9.4 percent for the 15.0+ inch class.

Estimated tree specific gravity for pond pine was obtained by using the following egression equation:

$$\text{Tree specific gravity (Y)} = 0.08030 + 0.80175(\text{sp. gr., 1 core}) \quad (1)$$

This equation had a correlation coefficient of 0.79, and a standard error of .031.

When the specific gravity of the 554 trees sampled by increment cores was adjusted to whole tree specific gravity by using equation (1), the average tree specific gravity was .474, with a standard error of .001.

The specific gravity of unextracted increment cores and the estimated tree specific gravity by three diameter classes are presented in table 2 for each Forest Survey Unit[2] sampled. Examination of these data revealed no geographic trends. This is in agreement with the report of McElwee and Zobel (1962) that there is no geographic pattern in specific gravity among six areas in North Carolina.

---

[2] Forest Survey Units are subdivisions of a state based in part on county boundaries and in part on physiography of the state. They are established for the purpose of sampling and reporting results efficiently.

Table 1.—*Unextracted and extracted increment core specific gravity of pond pine by counties and states*

State and county	Trees in sample	Mean d.b.h.	Mean age	Unextracted		Extracted		Difference between means
				Mean and standard error	Standard deviation	Mean and standard error	Standard deviation	
	Number	*Inches*	*Years*					*Percent*
orida								
Alachua	5	10.1	36	.499 (.013)	.029	.465 (.012)	.028	7.31
Duval	2	5.6	12	.444 (.035)	.050	.432 (.037)	.052	2.66
Nassau	2	10.6	23	.514 (.104)	.147	.474 (.104)	.147	8.44
Putnam	1	11.4	53	.518 (----)	. .	.481 (----)		7.69
St. Johns	3	10.2	23	.500 (.021)	.036	.469 (.018)	.032	6.62
Taylor	7	9.3	38	.519 (.012)	.033	.489 (.010)	.026	6.23
State total	20	9.5	32	.503 (.009)	.048	.472 (.008)	.044	6.57
orgia								
Appling	2	9.9	31	.510 (.048)	.067	.482 (.038)	.054	5.92
Atkinson	1	7.1	43	.545 (----)	—	.465 (----)	....	17.20
Berrien	2	10.9	20	.491 (.016)	.023	.463 (.016)	.023	6.05
Brantley	2	7.5	26	.534 (.032)	.045	.473 (.020)	.028	12.79
Bryan	1	4.8	21	.470 (----)	.	.426 (----)	. .	10.33
Bulloch	2	6.2	14	.420 (.040)	.056	.393 (.046)	.066	7.00
Burke	1	13.6	39	.508 (----)	.	.484 (----)	. . .	4.96
andler	1	9.2	20	.482 (----)	. .	.446 (----)		8.07
hatham	1	8.0	30	.492 (.)	. . .	.454 (----)	. .	8.37
hattahoochee	1	10.7	32	.510 (----)	....	.474 (----)	.	7.60
ook	8	9.0	30	.496 (.012)	.035	.468 (.013)	.036	6.09
ffingham	1	13.3	53	.508 (----)	.	.472 (. .)		7.63
vans	3	16.5	78	.537 (.049)	.085	.475 (.036)	.063	13.05
lynn	3	8.5	20	.499 (.036)	.062	.459 (.032)	.055	8.56
win	2	13.2	47	.492 (.010)	.014	.455 (.001)	.002	8.13
ff Davis	5	14.6	23	.474 (.020)	.046	.440 (.023)	.052	7.58
ee	8	6.4	14	.465 (.014)	.039	.435 (.013)	.037	6.86
ong	2	6.6	16	.457 (.008)	.011	.424 (.008)	.012	7.66

Table 1.—*Unextracted and extracted increment core specific gravity of pond pine by counties and states (continued)*

State and county	Trees in sample	Mean d.b.h.	Mean age	Unextracted		Extracted		Difference between means
				Mean and standard error	Standard deviation	Mean and standard error	Standard deviation	
	Number	*Inches*	*Years*					*Percent*
Georgia (continued)								
Lowndes	13	9.6	30	.487 (.013)	.047	.447 (.008)	.030	8.79
Mitchell	1	15.2	27	.515 (----)		.486 (----)	----	5.97
Pierce	2	8.6	44	.556 (.036)	.051	.522 (.035)	.049	6.41
Schley	1	6.6	22	.524 (----)	----	.491 (----)	----	6.72
Screven	1	19.4	28	.433 (---)	—	.392 (----)	----	10.46
State total	64	10.0	29	.491 (.004)	.046	.454 (.003)	.043	8.15
North Carolina								
Beaufort	31	9.6	32	.482 (.009)	.048	.446 (.005)	.030	8.19
Bertie	1	10.7	24	.506 (.)		.476 (----)	----	6.30
Bladen	26	9.2	25	.482 (.008)	.041	.452 (.007)	.036	6.71
Brunswick	9	9.7	47	.554 (.016)	.048	.483 (.010)	.031	14.63
Carteret	11	7.7	22	.494 (.016)	.052	.426 (.008)	.025	16.11
Columbus	7	7.1	19	.442 (.018)	.048	.418 (.019)	.050	5.75
Craven	22	8.2	29	.495 (.012)	.055	.465 (.012)	.057	6.36
Cumberland	7	9.7	54	.529 (.016)	.044	.461 (.017)	.044	14.73
Currituck	2	13.2	30	.465 (.054)	.076	.412 (.053)	.074	12.86
Duplin	2	9.3	21	.452 (.043)	.060	.432 (.042)	.060	4.75
Edgecombe	7	12.7	48	.497 (.012)	.030	.469 (.009)	.024	5.97
Gates	1	14.0	40	.557 (.)	---	.415 (----)	—	34.22
Green	3	18.2	35	.466 (.034)	.059	.412 (.016)	.028	13.20
Halifax	4	9.6	21	.471 (.045)	.090	.403 (.013)	.025	16.68
Hoke	2	17.9	82	.556 (.006)	.008	.522 (.006)	.008	6.71
Hyde	7	9.5	43	.507 (.018)	.048	.472 (.016)	.041	7.57
Jones	5	11.2	53	.518 (.023)	.052	.462 (.018)	.041	12.13
Lenoir	12	7.9	23	.468 (.010)	.033	.433 (.007)	.024	8.18
Martin	14	11.2	42	.491 (.014)	.052	.458 (.010)	.038	7.24
Montgomery	2	9.4	32	.475 (.036)	.050	.454 (.034)	.048	4.52
New Hanover	11	9.2	40	.497 (.013)	.043	.446 (.010)	.034	11.49
Onslow	17	9.9	27	.495 (.014)	.059	.456 (.007)	.038	8.69
Pamlico	6	14.2	46	.549 (.032)	.078	.466 (.014)	.033	17.82
Pasquotank	4	9.8	39	.454 (.015)	.030	.429 (.014)	.029	5.82
Pender	11	7.7	40	.504 (.022)	.073	.461 (.008)	.026	9.45
Perquimans	12	14.5	58	.500 (.009)	.030	.453 (.006)	.019	10.24
Robeson	12	8.9	22	.497 (.019)	.066	.439 (.009)	.032	13.20
Sampson	2	5.8	18	.484 (.003)	.004	.464 (.001)	.001	4.31
Tyrrell	17	10.4	32	.499 (.010)	.039	.462 (.007)	.030	8.04
Washington	2	8.5	44	.450 (.025)	.035	.427 (.018)	.026	5.51
Wayne	1	11.7	27	.454 ( )	----	.420 (----)	---	8.10
State total	270	9.8	34	.493 (.009)	.051	.451 (.007)	.040	9.31
South Carolina								
Aiken	4	12.7	29	.528 (.012)	.024	.504 (.011)	.023	4.81
Berkeley	26	9.4	28	.493 (.010)	.049	.466 (.007)	.037	5.67
Charleston	51	9.6	28	.495 (.011)	.060	.458 (.009)	.053	8.05
Chesterfield	5	10.5	33	.512 (.019)	.042	.450 (.019)	.042	13.88
Clarendon	2	7.6	20	.429 (.039)	.055	.412 (.034)	.049	4.25
Colleton	19	13.3	31	.474 (.006)	.028	.443 (.007)	.029	6.89
Dillon	5	9.7	26	.487 (.014)	.031	.464 (.016)	.037	4.91
Dorchester	16	10.3	35	.495 (.011)	.045	.467 (.011)	.042	6.07
Florence	21	12.2	36	.498 (.009)	.041	.462 (.009)	.040	7.88
Georgetown	14	10.4	38	.498 (.010)	.036	.466 (.008)	.031	6.92
Horry	15	9.8	27	.457 (.012)	.046	.429 (.011)	.042	6.62
Jasper	1	11.3	24	.427 (---)	----	.368 (----)	----	16.03
Marion	9	7.1	20	.458 (.018)	.055	.422 (.007)	.020	8.37
Orangeburg	2	11.6	26	.483 (.017)	.024	.454 (.012)	.017	6.40
Sumter	1	12.7	34	.440 (---)	---	.408 (----)	---	7.84
Williamsburg	5	13.0	33	.501 (.013)	.030	.459 (.017)	.037	9.15
State total	196	10.4	30	.488 (.004)	.049	.455 (.003)	.043	7.25
Virginia								
Isle of Wight	4	13.6	39	.483 (.019)	.039	.442 (.019)	.037	9.21
Total	554	10.1	32	.492 (.001)	.048	.454 (.001)	.037	8.37

Table 2.—*Specific gravity for pond pine by states and by Forest Survey Units within states*

State, survey unit, and number	Locations sampled	Diameter class	Trees sampled	Mean diameter of sampled trees	Mean age of sampled trees	Increment core specific gravity		Estimated tree specific gravity[1] mean and standard error	Approximate timber volume[2]
						Mean and standard error	Standard deviation		
	Number	*Inches*	*Number*	*Inches*	*Years*				*Million cu. ft.*
Florida									
Northeast (1)	6	4.0-8.9	9	6.6	26	.505 (.020)	.061	.485 (.010)	18.5
		9.0-14.9	10	11.4	37	.509 (.008)	.034	.488 (.010)	35.3
		15.0+	1	16.2	32	.431 (----)	..	.426 ( )	9.3
Georgia									
Southeast (1)	14	4.0-8.9	12	6.5	22	.490 (.018)	.060	.473 (.009)	39.5
		9.0-14.9	11	11.9	31	.492 (.013)	.041	.475 (.009)	62.7
		15.0+	4	19.5	64	.517 (.040)	.080	.495 (.014)	24.2
Southwest (2)	5	4.0-8.9	10	6.4	25	.485 (.004)	.023	.469 (.010)	8.9
		9.0-14.9	14	11.6	35	.494 (.003)	.046	.476 (.026)	14.0
		15.0+	2	16.9	30	.508 (.006)	.012	.488 (.022)	5.1
Central (3)	4	4.0-8.9	8	6.1	15	.474 (.010)	.041	.460 (.010)	4.2
		9.0-14.9	3	11.3	28	.492 (.016)	.031	.475 (.017)	23.3
		15.0+	0	----	----	----	----	----	----
State total	23	4.0-8.9	30	6.4	21	.484 (.005)	.048	.468 (.005)	52.6
		9.0-14.9	28	11.7	33	.493 (.002)	.040	.476 (.005)	100.0
		15.0+	6	18.6	52	.514 (.020)	.065	.492 (.014)	29.3
North Carolina									
Southern Coastal Plain (1)	15	4.0-8.9	63	6.6	22	.479 (.006)	.053	.464 (.004)	146.2
		9.0-14.9	54	11.0	39	.510 (.011)	.061	.489 (.004)	229.7
		15.0+	10	17.5	54	.504 (.020)	.056	.485 (.010)	39.8
Northern Coastal Plain (2)	15	4.0-8.9	61	7.1	22	.486 (.004)	.045	.470 (.004)	103.9
		9.0-14.9	62	12.0	41	.497 (.008)	.060	.479 (.004)	232.7
		15.0+	18	16.9	64	.505 (.017)	.045	.485 (.007)	76.6
Piedmont (3)	1	4.0-8.9	1	7.9	24	.446 (----)	.	.438 (----)	2.2
		9.0-14.9	1	11.0	39	.503 (.)	. .	.484 (----)	2.1
		15.0+	0	----	----	----	----	----	----
State total	31	4.0-8.9	125	6.9	22	.482 (.008)	.045	.467 (.003)	252.3
		9.0-14.9	117	11.5	40	.503 (.009)	.053	.484 (.003)	464.5
		15.0+	28	17.1	61	.504 (.009)	.046	.485 (.005)	116.4
South Carolina									
Southern Coastal Plain (1)	5	4.0-8.9	8	6.3	19	.463 (.007)	.026	.452 (.010)	24.0
		9.0-14.9	24	11.3	34	.495 (.008)	.041	.477 (.066)	73.6
		15.0+	10	18.1	38	.485 (.015)	.045	.469 (.010)	31.0
Northern Coastal Plain (2)	11	4.0-8.9	68	6.8	22	.479 (.006)	.060	.464 (.004)	68.6
		9.0-14.9	71	11.7	34	.498 (.005)	.046	.480 (.003)	141.2
		15.0+	15	16.2	44	.486 (.010)	.047	.470 (.008)	55.9
State total	16	4.0-8.9	76	6.7	21	.477 (.006)	.060	.463 (.003)	92.6
		9.0-14.9	95	11.6	34	.497 (.004)	.046	.479 (.003)	214.8
		15.0+	25	17.0	42	.486 (.006)	.042	.470 (.006)	89.6
irginia									
Coastal Plain (1)	1	4.0-8.9	0	---	----	----	---	--	1.1
		9.0-14.9	4	13.6	39	.483 (.019)	.039	.468 (.014)	6.0
		15.0+	0	----	----	----	----	----	4.4
All States	77	4.0-8.9	240	6.8	22	.482 (.008)	.046	.467 (.002)	417.1
		9.0-14.9	254	11.6	37	.500 (.001)	.047	.481 (.002)	820.6
		15.0+	60	17.2	52	.496 (.001)	.042	.478 (.004)	249.0
otal all classes	77		554	10.1	32	.492 (.001)	.048	.474 (.001)	1,486.7

[1] Estimates were made with equation (1): $Y = 0.08030 + 0.80175$ (sp. gr., 1 core).

[2] From Forest Survey data of the Southern and Southeastern Forest Experiment Stations.

Increment Core/Tree Specific Gravity Relationships -- Simple Linear and Multiple Regression Analysis

A discussion of the increment core/tree specific gravity relationships is given in an office report available upon request and will not be treated in detail here. All regression equations developed from these data for predicting tree specific gravity of pond pine are presented in table 3 in the Appendix. Table 4 in the Appendix contains the means and standard deviations of all the independent variables used to analyze increment core/tree specific gravity relationships.

From these data, the best equation developed for predicting tree specific gravity of pond pine was:

$$\begin{aligned} Y = {} & 0.14923 + 0.65957(\text{sp. gr., 2 cores}) \\ & + 0.00089(\text{total height}) \\ & - 0.00435(\text{d.b.h.}) \qquad (2) \end{aligned}$$

This equation had a correlation coefficient of .83 and the standard error was .023.

Equation (1) was used to adjust th increment core specific gravity to tree specific gravity. It was used instead of equatio (2) because only one core was obtaine from each sample tree. Equation (1) wa the best single-core equation. It had a correlation coefficient of .79 and a standar error of .031.

Relationship of Unextracted and Extracted Specific Gravity

The specific gravity of all incremen cores was determined in both the unextracted and extracted condition. From these data the following regression equation for predicting extracted specific gravity was developed:

$$Y = 0.12908 + 0.66027\,X_1 \qquad (3)$$

where: Y = specific gravity of 1 extracted increment core
X_1 = specific gravity of 1 unextracted increment core

Equation (3) has a correlation coefficient of .81 and a standard error of .023.

SUMMARY AND CONCLUSIONS

The average specific gravity of pond pine increment cores was .492. After extractives were removed, the same increment cores had an average specific gravity of .454, a difference of 8.4 percent. No geographical trends in specific gravity were apparent from plotted data.

The best equation developed for predicting tree specific gravity contained three independent variables: (1) specific gravity of two increment cores, (2) total height, and (3) d.b.h. These variables were associated with 69 percent of the variation about regression. The standard error of estimate was .023. Since only one increment core was removed from sample trees in the survey, an equation involving only one increment core was used to estimate tree specific gravity from increment core specific gravity. The best single core equation involved only one independent variable—the specific gravity of one increment core. This variable was associated with 62 percent of the variation about regression.

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APPENDIX

Computational Procedures

1. Increment core specific gravity $= \dfrac{\text{ovendry weight of core}}{\text{green weight of core} - .3464\,(\text{ovendry weight of core})}$

2. Disk specific gravity $= \dfrac{\text{ovendry weight of disk}}{\text{displaced volume of disk}}$

3. Bolt specific gravity $= \dfrac{\text{specific gravity top disk} + \text{specific gravity bottom disk}}{2}$

4. Tree specific gravity $= \dfrac{\sum_{1-n} (\text{bolt volume} \times \text{bolt specific gravity})}{\sum_{1-n} \text{bolt volumes}}$

5. Bolt volume = bolt length, feet $\times \left[\dfrac{.005454\,(\text{d.i.b.})_t^2 + .005454\,(\text{d.i.b.})_b^2}{2} \right]$

   where: t = top of bolt
   b = base of bolt

6. (a) Mean core specific gravity $\bar{x} = \dfrac{\Sigma_i \Sigma_j X_{ij}}{m_1 n_1}$

   where: X_{ij} = the core specific gravity for the jth tree at the ith location
   m_1 = number of trees at each location
   n_1 = number of locations

   (b) The standard deviation of individuals was estimated from the sample range of the core specific gravities using the tabular values of the ratio of the standard deviation to the range.

7. Tree specific gravities were estimated from regression by:

   (a) Tree specific gravity (Y) = $b_0 + b_1 X_1$

   where: X_1 = specific gravity of 1 unextracted core

   (b) The standard error of the predicted mean tree specific gravity was estimated by--

$$S_{\hat{y}} = \left[S^2_{y.x} \left(\frac{1}{n} + \frac{(\bar{x}_1 - \bar{x}_2)^2}{\Sigma x_2^2} \right) \right]^{\frac{1}{2}}$$

   where: $S^2_{y.x}$ = residual mean squares
   n = number of trees in large sample
   $\bar{x}_1$ = mean unextracted core specific gravity of large sample
   $\bar{x}_2$ = mean unextracted core specific gravity of small sample

   (c) The standard error of the core mean was approximated by the following computation when the variances were pooled to obtain the mean core specific gravity of more than one location:

$$\text{standard error} = \sqrt{\frac{K}{(\Sigma n_i)^2} \left(\frac{\Sigma S_i^2 + \bar{x}^2 \Sigma n_i^2 - 2\bar{x} \Sigma n_i S_i}{K-1} \right)}$$

   where: K = the number of locations at which trees were bored for specific gravity
   S_i = the sum of specific gravities of cores at the ith location (= $\Sigma_j X_{ij}$)

   (d) When variances were not pooled the standard error of the mean was approximated by--

$$\text{standard error} = \frac{S}{\sqrt{n}}$$

   where: S = standard deviation estimated from the sample range of core specific gravities
   n = number of observations in sample

8. Percentage difference in specific gravity due to extraction $= \dfrac{\text{unextracted core sp. gr.} - \text{extracted core sp. gr.}}{\text{extracted core sp. gr.}} \times 100$

Table 8. Regression [illegible] errors about regressions for pond pine
increment core/tree specific gravity relationships

Regression equations	r	r²	Standard error
Tree specific gravity (Y):			
Y = 0.14923 + 0.65957 (sp. gr., 2 cores) + 0.00089 (total height) — 0.00435 (d.b.h.)	0.83	0.69	0.028
Y = 0.16490 + 0.67206 (sp. gr., 2 extracted cores) + 0.00117 (total height) — 0.00557 (d.b.h.)	0.83	0.69	0.028
Y = 0.13153 + 0.61156 (weighted sp. gr., 2 cores) + 0.00097 (total height) — 0.04802 (merch. vol./age)	0.82	0.67	0.028
Y = 0.13188 + 0.67400 (weighted sp. gr., 2 extracted cores) + 0.00117 (total height) — 0.00343 (d.b.h.)	0.82	0.67	0.029
Y = 0.15316 + 0.56064 (sp. gr., outer 2/3 of 2 cores) + 0.00103 (total height) — 0.04911 (merch. vol./age)	0.82	0.67	0.029
Y = 0.15089 + 0.62480 (sp. gr., outer 2/3 of 2 extracted cores) + 0.00119 (total height) — 0.00338 (d.b.h.)	0.82	0.67	0.029
Y = 0.08785 + 0.70873 (weighted sp. gr., 2 cores) + 0.00059 (total height)	0.82	0.67	0.029
Y = 0.10287 + 0.79978 (sp. gr., 2 cores) — 0.00224 (d.b.h.)	0.82	0.67	0.029
Y = 0.15284 + 0.52609 (sp. gr., outer 1/3 of 2 extracted cores) + 0.00172 (total height) — 0.07070 (merch. vol./age)	0.81	0.66	0.030
Y = 0.18950 + 0.59735 (sp. gr., 1 extracted core) + 0.00141 (total height) — 0.00589 (d.b.h.)	0.81	0.66	0.030
Y = 0.14629 + 0.56792 (weighted sp. gr., 1 core) + 0.00115 (total height) — 0.05531 (merch. vol./age)	0.81	0.66	0.030
Y = 0.09711 + 0.72014 (sp. gr., outer 2/3 of 2 extracted cores) + 0.00072 (total height)	0.81	0.66	0.030
Y = 0.07769 + 0.78282 (weighted sp. gr., 2 cores)	0.81	0.66	0.029
Y = 0.07612 + 0.77381 (weighted sp. gr., 2 extracted cores) + 0.00069 (total height)	0.81	0.66	0.029
Y = 0.11032 + 0.65581 (sp. gr., outer 2/3 of 2 cores) + 0.00064 (total height)	0.81	0.66	0.029
Y = 0.07932 + 0.80701 (sp. gr., 2 cores)	0.81	0.66	0.029
Y = 0.17770 + 0.45127 (sp. gr., outer 1/3 of 2 cores) + 0.00169 (total height) — 0.07411 (merch. vol./age)	0.80	0.64	0.030
Y = 0.11053 + 0.86039 (sp. gr., 2 extracted cores) — 0.00294 (d.b.h.)	0.80	0.64	0.030
Y = 0.10174 + 0.73089 (sp. gr., outer 2/3 of 2 cores)	0.80	0.64	0.030
Y = 0.06413 + 0.86706 (weighted sp. gr., 2 extracted cores)	0.80	0.64	0.030
Y = 0.15940 + 0.60226 (weighted sp. gr., 1 extracted core) + 0.00139 (total height) — 0.00397 (d.b.h.)	0.80	0.64	0.030
Y = 0.14291 + 0.67813 (sp. gr., 1 core) + 0.02354 (total height/age) — 0.12572 (d.b.h./age)	0.80	0.64	0.030
Y = 0.09416 + 0.68244 (weighted sp. gr., 1 core) + 0.00071 (total height)	0.80	0.64	0.030
Y = 0.13670 + 0.72403 (sp. gr., 1 core) — 0.05946 (d.b.h./age)	0.79	0.62	0.030
Y = 0.17392 + 0.50488 (sp. gr., outer 2/3 of 1 core) + 0.00123 (total height) — 0.05996 (merch. vol./age)	0.79	0.62	0.030
Y = 0.17748 + 0.46544 (sp. gr., outer 1/3 of 1 extracted core) + 0.00189 (total height) — 0.08080 (merch. vol./age)	0.79	0.62	0.031
Y = 0.18017 + 0.51631 (sp. gr., outer 2/3 of 1 extracted core) + 0.00138 (total height) — 0.06956 (merch. vol./age)	0.79	0.62	0.031
Y = 0.08693 + 0.81138 (sp. gr., outer 2/3 of 2 extracted cores)	0.79	0.62	0.031
Y = 0.08263 + 0.86394 (sp. gr., 2 extracted cores)	0.79	0.62	0.031
Y = 0.09533 + 0.71503 (weighted sp. gr., 1 extracted core) + 0.00085 (total height)	0.79	0.62	0.031
Y = 0.09036 + 0.65535 (sp. gr., outer 1/3 of 2 extracted cores) + 0.00130 (total height)	0.79	0.62	0.031
Y = 0.08030 + 0.80175 (sp. gr., 1 core)	0.79	0.62	0.031
Y = 0.20342 + 0.39324 (sp. gr., outer 1/3 of 1 core) + 0.00185 (total height) — 0.08536 (merch. vol./age)	0.78	0.61	0.031
Y = 0.08225 + 0.77103 (weighted sp. gr., 1 core)	0.78	0.61	0.031
Y = 0.12013 + 0.62309 (sp. gr., outer 2/3 of 1 core) + 0.00075 (total height)	0.78	0.61	0.031
Y = 0.11777 + 0.56918 (sp. gr., outer 1/3 of 2 cores) + 0.00123 (total height)	0.78	0.61	0.031
Y = 0.11891 + 0.65742 (sp. gr., outer 2/3 of 1 extracted core) + 0.00086 (total height)	0.78	0.61	0.032
Y = 0.11538 + 0.72151 (sp. gr., 1 extracted core) + 0.00066 (total height)	0.77	0.59	0.032
Y = 0.10801 + 0.60681 (sp. gr., outer 1/3 of 1 extracted core) + 0.00144 (total height)	0.77	0.59	0.032
Y = 0.11005 + 0.71110 (sp. gr., outer 2/3 of 1 core)	0.77	0.59	0.032
Y = 0.08338 + 0.82330 (weighted sp. gr., 1 extracted core)	0.76	0.58	0.032
Y = 0.10201 + 0.81775 (sp. gr., 1 extracted core)	0.76	0.58	0.033
Y = 0.13570 + 0.52491 (sp. gr., outer 1/3 of 1 core) + 0.00135 (total height)	0.76	0.58	0.033
Y = 0.10860 + 0.76216 (sp. gr., outer 2/3 of 1 extracted core)	0.75	0.56	0.033
Y = 0.09623 + 0.76675 (sp. gr., outer 1/3 of 2 extracted cores)	0.73	0.53	0.034
Y = 0.12273 + 0.66913 (sp. gr., outer 1/3 of 2 cores)	0.73	0.53	0.034
Y = 0.12195 + 0.71447 (sp. gr., outer 1/3 of 1 extracted core)	0.69	0.48	0.036
Y = 0.14538 + 0.62609 (sp. gr., outer 1/3 of 1 core)	0.69	0.48	0.036

Table 4.—*Mean and standard deviation of the dependent and independent variables used to develop regression equations for the increment core/tree specific gravity relationships for pond pine*

Variables	Mean	Standard deviation
Dependent		
Weighted tree specific gravity	0.477	0.050
Independent		
D.b.h.	8.932	2.455
Total height	46.880	12.363
Age	32.040	12.259
Merchantable volume	8.190	5.574
D.b.h./age	0.302	0.105
1/age	0.035	0.012
Merchantable volume/age	0.253	0.149
Total height/age	1.550	0.363
Specific gravity, 1 core	0.495	0.049
Specific gravity, outer 2/3 of 1 core	0.516	0.053
Specific gravity, outer 1/3 of 1 core	0.529	0.054
Specific gravity, 2 cores	0.493	0.050
Specific gravity, outer 2/3 of 2 cores	0.513	0.054
Specific gravity, outer 1/3 of 2 cores	0.529	0.054
Weighted specific gravity, 1 core	0.512	0.050
Weighted specific gravity, 2 cores	0.510	0.051
Specific gravity, 1 extracted core	0.458	0.046
Specific gravity, outer 2/3 of 1 extracted core	0.483	0.049
Specific gravity, outer 1/3 of 1 extracted core	0.497	0.048
Specific gravity, 2 extracted cores	0.456	0.045
Specific gravity, outer 2/3 of 2 extracted cores	0.481	0.048
Specific gravity, outer 1/3 of 2 extracted cores	0.496	0.047
Weighted specific gravity, 1 extracted core	0.478	0.046
Weighted specific gravity, 2 extracted cores	0.476	0.046

Taras, Michael A., and Saucier, Joseph R.
1970. Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States. Part VI--Pond Pine (Pinus serotina Michx.). Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-65, 12 pp.

Pond pine (Pinus serotina Michx.) was sampled at 77 locations over a major part of its range. Specific gravity was determined for the same increment cores, unextracted then extracted. The average specific gravity of unextracted increment cores was .492, while the extracted increment core specific gravity was .454, a difference of 8.4 percent. Increment core/tree specific gravity relationships were examined, and equations were developed for predicting tree specific gravity from increment cores. The average tree specific gravity of the species was estimated to be .474. No geographic trends were found in the specific gravity of pond pine.

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Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States

Part VII--South Florida Slash Pine (*Pinus elliottii var. densa* Little & Dorman)

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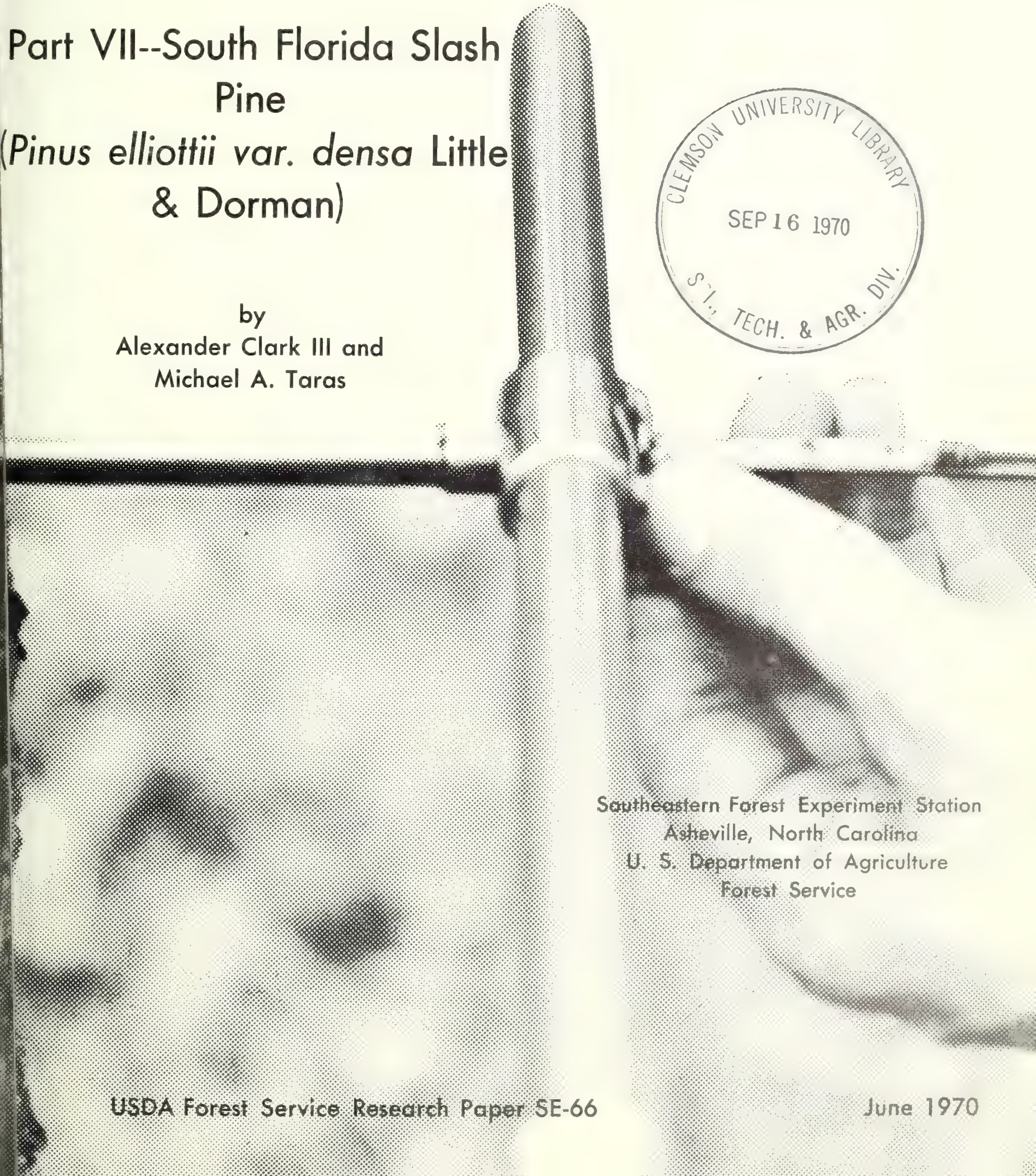
by
Alexander Clark III and
Michael A. Taras



Southeastern Forest Experiment Station
Asheville, North Carolina
U. S. Department of Agriculture
Forest Service

USDA Forest Service Research Paper SE-66

June 1970

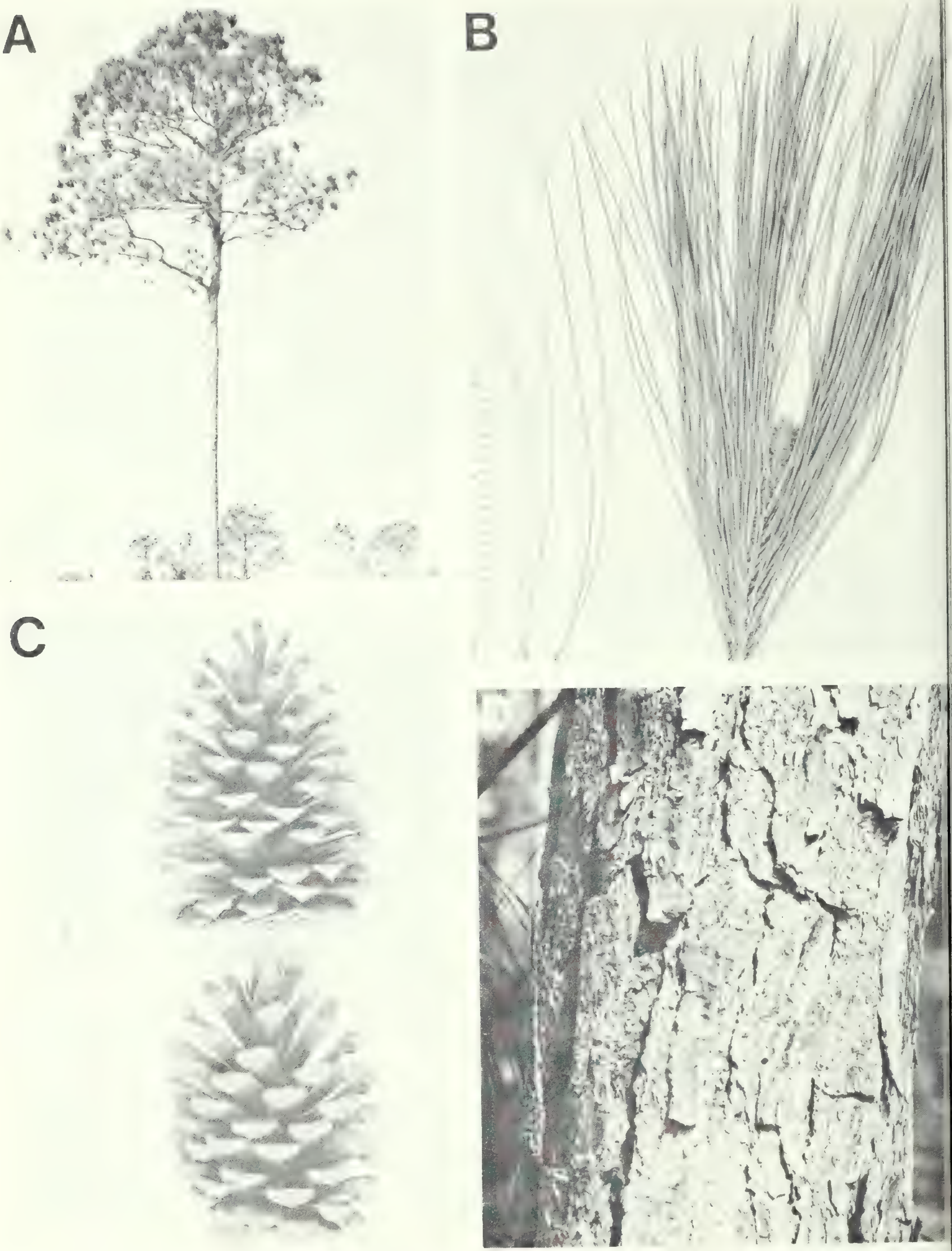


Figure 1.—*Botanical features of South Florida slash pine*: (*A*) *mature tree*, (*B*) *needles*, (C) *partially opened cones*, (*D*) *mature bark.*

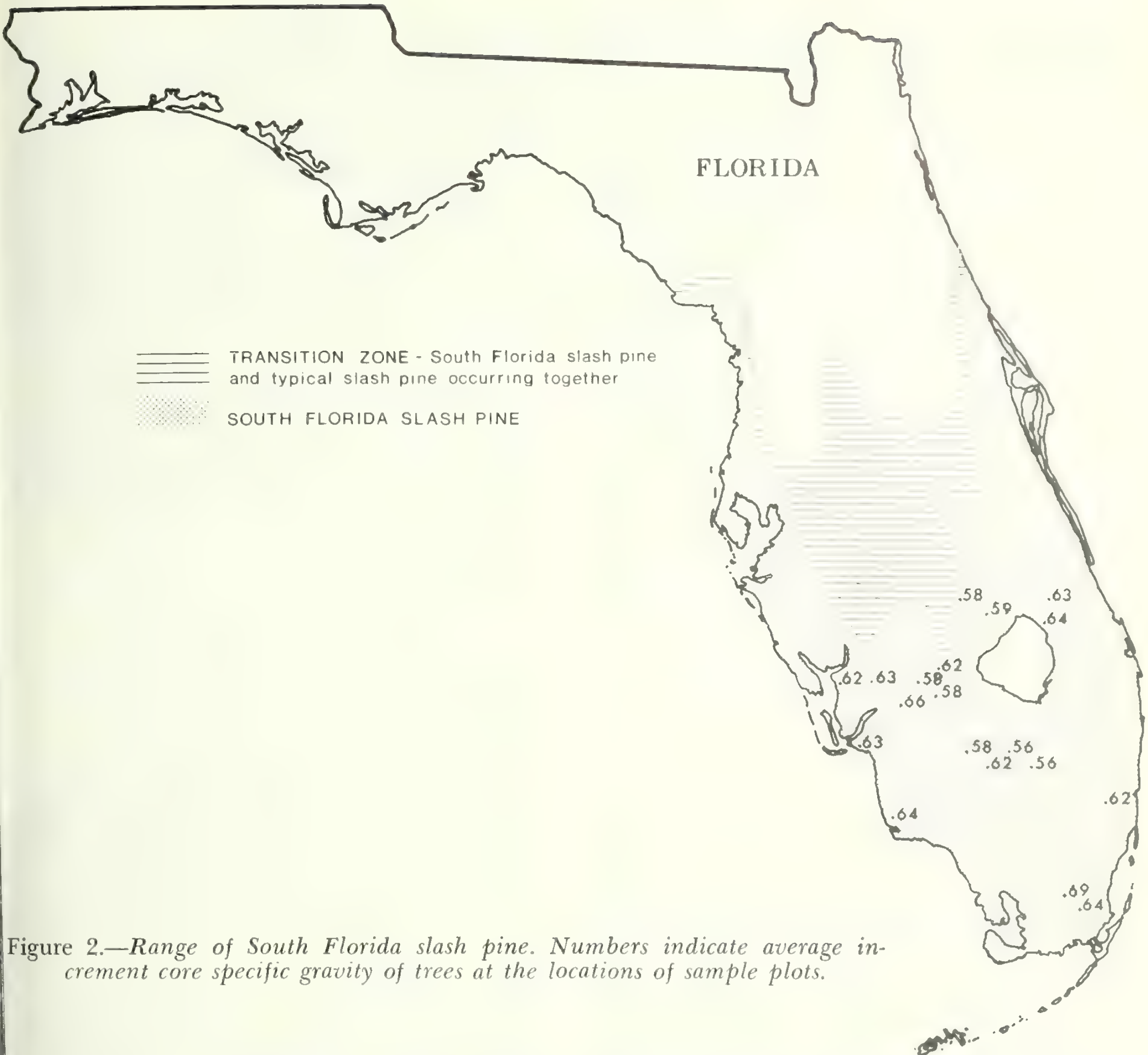


Figure 2.—*Range of South Florida slash pine. Numbers indicate average increment core specific gravity of trees at the locations of sample plots.*

shown in figure 2. Squillace (1966), however, found no evidence supporting the existence of two distinct varieties in the transition zone or of hybrids between *densa* and *elliottii.* He states that hybridization and introgression may have occurred during the Pleistocene or earlier and that subsequent natural selection has apparently obscured it. Thus, it is almost impossible to separate mature trees of the two varieties in the transition zone.

South Florida slash pine differs from typical slash pine in having grasslike seedings with short stems, many crowded needles, very thick hypocotyls, and thick taproots (Little and Dorman 1952). The epithet (*densa)* refers to the dense wood of mature rees, which have a high proportion of latewood, and also to the crowded needles, thick hypocotyls, and thick taproots of the grasslike seedlings. Variety *densa* is more fire resistant and less susceptible to tip moth attack than variety *elliottii,*[2] but has a poorer survival rate and grows slower (White and Saucier 1966).

Field Sampling Procedure

To meet the objectives of the study, 19 plots were sampled throughout the range of South Florida slash pine. The available data indicated that patterns of variation in specific gravity of South Florida slash pine are similar to those of the other minor species of southern yellow pine. Thus, 15 trees were sampled at each location to make maximum use of sampling funds, as suggested by Clark and Ike (1970).

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[2] Bethune, J. E. A comparison study of North and South Florida slash pine. 1963. (Unpublished report of Southeast. Forest Exp. Sta., Asheville, N. C.)

The plots were selected randomly over the range of the variety using a 6-mile grid (fig. 2). The stand nearest the randomly selected location was sampled when possible. At each sample location, a random azimuth was selected along which the first 15 trees, over 5.0 inches d.b.h. and showing no signs of heartrot, were sampled by removing two increment cores from opposite sides of each tree. Total height, merchantable height to a 4-inch top, and d.b.h. of each sample tree were recorded. The trees to be used for analyzing increment core/tree specific gravity relationships were randomly selected at four locations within the range of South Florida slash pine. Two increment cores were taken from each of 10 trees at each location before they were felled. Beginning at the butt end of the tree, 1-inch-thick disks were cut at 5-foot intervals to a 4-inch top. Total height and merchantable height to a 4-inch top were recorded, along with diameter of each disk.

Laboratory Procedures

The specific gravity of all unextracted and extracted increment cores was determined by the maximum moisture method described by Smith (1954). All cores were subjected to a vacuum treatment for several days to insure complete water saturation. Wood disks were soaked for several days and their specific gravity was determined by the buoyancy method described by Heinrichs (1954). The results are based on green volume and ovendry weight.

Increment cores from all trees were extracted after unextracted specific gravity was determined. These extractions were made with a mixture of two parts benzene and one part ethyl alcohol for a period of 24 hours. Following extraction the cores were dried, saturated with water, and their specific gravity was determined by the maximum moisture method. No wood disks were extracted.

The increment cores from the trees collected to analyze increment core/tree specific gravity relationships were divided into three equal parts, and the specific gravity of each segment was determined. The purpose was to obtain a weighted increment core specific gravity and to examine the relationship of parts (1/3 or 2/3) of whole increment cores to total tree specific gravity. Weighted core specific gravity was determined by weighting the specific gravities of segments by the cross-sectional areas the segments represented.

The average specific gravity of the individual 5-foot bolts within each tree was computed as the mean of the bolt's terminal disks. The average specific gravity of the tree was determined by weighting the average bolt specific gravity by bolt volume. Formulas for all these computations are shown in the Appendix. A discussion of the analysis of the increment core/tree specific gravity relationship data is presented in an office report available from the Forestry Sciences Laboratory, Carlton Street, Athens Georgia 30601.

RESULTS AND DISCUSSION

South Florida Slash Pine Specific Gravity and Its Variation

The average specific gravity of *unextracted* South Florida slash pine increment cores was .615, based on the average of two whole increment cores from 285 sample trees collected over the range of the variety. The standard error of the mean increment core specific gravity was .008, and the standard deviation about the mean of the individual observations was .068.

Variation among unextracted increment core specific gravity of South Florida slash pine was greater than that of the other minor species of yellow pine. Squillace (1966) found more variation in morphological traits of both varieties of slash pine in south Florida and other extremities of their range than in central Florida or Georgia He states: "This large amount of variation in certain geographic areas may be due to the existence of severe environmental factors which fluctuate greatly in time; resulting in maintenance of a greater variety of genotypes."

The average specific gravity of *extracted* increment cores was .547; standard error was .008, and standard deviation of individuals was .044. The specific gravity of unextracted cores was 12.4 percent higher than the extracted core specific gravity. This was much higher than the 6.0- to 7.5-percent difference reported for the four major southern yellow pines (Taras and Saucier 1967) and considerably higher than the difference found in any of the other minor species of yellow pine. The average increment core specific gravity of South Florida slash pine trees in the 5.0 to 8.9 inch diameter class decreased 9.4 percent when extractives were removed, trees in the 9.0 to 14.9 inch class decreased 15.6 percent, and those in the 15.0+ inch class decreased 18.8 percent.

Table 1 shows the average specific gravity of unextracted and extracted increment cores by plots and the percentage difference resulting from removal of extractives. Table 1 also includes sample size, mean age, and mean d.b.h.

The estimated average tree specific gravity for South Florida slash pine was computed with the following regression equation:

$$\text{Tree specific gravity } (Y) = 0.23910 + 0.68818(\text{sp. gr., 2 extracted cores}) - 0.10225(\text{d.b.h./age}) \qquad (1)$$

When the specific gravity of 285 trees sampled by increment cores was adjusted to whole tree specific gravity by using equation (1), the average tree specific gravity was .580, with a standard error of .003.

The specific gravity of unextracted increment cores and the estimated tree specific gravity by three diameter classes (5.0-8.9 inches, 9.0-14.9 inches, and 15.0+ inches) are presented in table 2 for each Forest Survey Unit[3] sampled.

The average unextracted increment core specific gravity of each plot sampled is shown in figure 2 to illustrate specific gravity changes with geographic location. The data in figure 2 indicate that a geographic difference in specific gravity exists between trees growing on the coast and those growing farther inland. The average increment core specific gravity of trees growing within 25 miles of the Atlantic and Gulf coasts was .639; the inland trees averaged .597. By covariance analysis, the unextracted and extracted increment core specific gravities were adjusted for the effects of age and d.b.h. The adjusted mean unextracted specific gravity of coastal trees was .632; the adjusted mean unextracted specific gravity

Table 1.—*Specific gravity of unextracted and extracted increment cores from South Florida slash pine*

Plot umber	County in Florida	Trees in sample	Mean d.b.h.	Mean age	Unextracted		Extracted		Difference between means
					Mean and standard error	Standard deviation	Mean and standard error	Standard deviation	
		Number	*Inches*	*Years*					*Percent*
1	Charlotte	15	11.2	34	.622 (.009)	.036	.533 (.007)	.027	16.70
2	Charlotte	15	9.5	27	.626 (.013)	.049	.563 (.009)	.037	11.19
3	Collier	15	6.9	30	.642 (.017)	.066	.577 (.013)	.050	11.26
4	Lee	15	11.3	37	.632 (.016)	.062	.522 (.007)	.028	21.07
5	Hendry	15	8.6	21	.564 (.018)	.069	.524 (.014)	.055	7.63
6	Hendry	15	8.1	18	.556 (.008)	.032	.506 (.008)	.031	9.88
7	Hendry	15	10.9	44	.658 (.017)	.065	.554 (.008)	.033	18.77
8	Hendry	15	7.4	19	.581 (.011)	.041	.548 (.009)	.035	6.02
9	Hendry	15	7.0	21	.615 (.009)	.036	.577 (.007)	.027	6.58
10	Okeechobee	15	10.5	36	.589 (.019)	.074	.523 (.008)	.031	12.62
11	Martin	15	11.0	33	.640 (.015)	.057	.549 (.012)	.046	16.58
12	Glades	15	8.5	32	.578 (.028)	.110	.510 (.014)	.054	13.33
13	Glades	15	8.8	34	.620 (.009)	.035	.550 (.008)	.032	12.73
14	St. Lucie	15	10.3	30	.629 (.013)	.048	.567 (.011)	.044	10.93
15	Highlands	15	9.1	25	.583 (.016)	.060	.505 (.011)	.041	15.44
16	Dade	15	8.4	37	.645 (.016)	.063	.588 (.012)	.045	9.69
17	Dade	15	8.2	34	.692 (.014)	.052	.622 (.010)	.037	11.25
18	Broward	15	10.0	34	.626 (.016)	.060	.551 (.008)	.029	13.61
19	Glades	15	9.9	28	.583 (.018)	.068	.513 (.010)	.038	13.64
	Total	285	9.2	30	.615 (.008)	.068	.547 (.008)	.044	12.43

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[3] Forest Survey Units are subdivisions of a state based in part on county boundaries and in part on physiography of the state. They are established for the purpose of sampling and reporting results efficiently.

Table 2.—*Specific gravity for South Florida slash pine by Forest Survey Units*

Forest Survey Unit and number	Locations sampled	Diameter class	Trees sampled	Unextracted increment core specific gravity		Estimated tree specific gravity[1] mean and standard error
				Mean and standard error	Standard deviation	
	Number	*Inches*	*Number*			
Central (3)	3	5.0-8.9	17	.570 (.014)	.058	.564 (.013)
		9.0-14.9	26	.623 (.016)	.049	.566 (.010)
		15.0+	2	.563 (.030)	.060	.540 (.038)
Southern (4)	16	5.0-8.9	131	.594 (.014)	.063	.579 (.005)
		9.0-14.9	105	.645 (.007)	.060	.587 (.005)
		15.0+	4	.674 (.029)	.060	.586 (.027)
All Units	19	5.0-8.9	148	.591 (.012)	.063	.577 (.004)
		9.0-14.9	131	.641 (.002)	.060	.583 (.005)
		15.0+	6	.637 (.037)	.084	.571 (.022)
Total all classes	19		285	.615 (.008)	.068	.580 (.003)

[1] Estimates were made with equation (1):
$Y = 0.23910 + 0.68818(\text{sp. gr., 2 extracted cores}) - 0.10225(\text{d.b.h./age})$.

of the inland trees was .602 (table 3). The difference in the adjusted data between inland trees and coastal trees was statistically significant at the .01 probability level (table 4), indicating that geographic variation exists. The percentage difference between unextracted and extracted specific gravity of increment cores of coastal trees was 13.1, while the percentage difference of the cores of inland trees was 12.0. This indicates that the geographic variation is in wood specific gravity and not in extractive content.

Increment Core/Tree Specific Gravity Relationships—Simple Linear and Multiple Regression Analyses

A discussion of the increment core/tree specific gravity relationships is given in an office report available upon request and will not be treated in detail here. All regression equations developed from these data for predicting tree specific gravity of South Florida slash pine are in table 5 in the Appendix.

The best equation developed from these data for predicting tree specific gravity of South Florida slash pine was:

$$\begin{aligned} Y = {} & 0.18589 + 0.80731(\text{sp. gr., outer } 2/3 \text{ of 2 extracted cores}) \\ & - 0.03267(\text{total height}/\text{age}) \\ & - 0.00280(\text{d.b.h.}) \end{aligned} \tag{2}$$

This equation had a correlation coefficient of .91 and accounted for 83 percent of the variation about regression.

Equation (1) was used in this study to adjust South Florida slash pine increment core specific gravity to tree specific gravity. This equation was used instead of the best one developed—Equation (2)—because of the time and increased cost involved in obtaining specific gravity values for segmented cores The equation used had a correlation coefficient of .88 and accounted for 77 percent of the variation about regression, which was 6 percent less than accounted for by the best equation.

Table 3.—*The unadjusted and adjusted mean increment core specific gravity of inland and coastal South Florida slash pine: (Adjusted for age and d.b.h. by covariance analysis)*

Areas	Trees sampled	Mean d.b.h.	Mean age	Mean increment core specific gravity			
				Unextracted		Extracted	
				Unadjusted	Adjusted	Unadjusted	Adjusted
	Number	*Inches*	*Year*				
Inland	165	9.1	28	.597	.602	.533	.535
Coastal	120	9.5	33	.639	.632	.565	.563
Variety average		9.2	30	.615		.547	

Table 4.—*Analysis of covariance of South Florida slash pine specific gravity from coastal and inland locations*

UNEXTRACTED SPECIFIC GRAVITY

Source	d.f.	Y Y	Sums of squares (due to regression)	Sums of squares (about regression)	d.f.	Mean squares
Between areas	1	0.1247				
Within areas	283	1.0978	0.3212	0.7766	281	0.0028
Treatments + error	284	1.2226	0.3872	0.8353	282	
Area means adjusted for age and d.b.h.				0.0587	1	0.0587**
EXTRACTED SPECIFIC GRAVITY						
Between areas	1	0.0741				
Within areas	283	0.6022	0.0383	0.5639	281	0.0020
Treatments + error	284	0.6763	0.0610	0.6153	282	
Area means adjusted for age and d.b.h.				0.0514	1	0.0514**

**Significant at the .01 probability level.

elationship of Unextracted and Extracted pecific Gravity

The specific gravity of all increment ores was determined in both the unextract-d and extracted condition. From these data, regression equation for predicting ex-racted specific gravity from unextracted pecific gravity was developed. Equation (3) ad a correlation coefficient of .77:

$$Y = 0.19406 + 0.57342 X_1 \qquad (3)$$

Where Y = specific gravity of 2 extracted increment cores
X_1 = specific gravity of 2 unextracted increment cores

Higher correlations have been reported or other minor species: spruce pine, r = 8 (Taras and Saucier 1968); Table-Mountain pine, r = .87 (Clark and Saucier 1969); irginia pine, r = .86 (Clark and Wahlgren 970).

SUMMARY AND CONCLUSIONS

The average specific gravity of South lorida slash pine increment cores taken at .b.h. was .615. This is the highest average ncrement core specific gravity found for ny of the yellow pines, both major and inor species. After extraction, the same ncrement cores had an average specific ravity of .547, a difference of 12.4 percent. outh Florida slash pine contained more extractives than any other yellow pine species examined in this laboratory.

The best equation developed for predicting South Florida slash pine tree specific gravity involved three independent variables: (1) specific gravity of the outer 2/3 of two cores; (2) total height, and (3) d.b.h. These variables were associated with 83 percent of the variation about regression. Since the increment cores taken in the survey were not segmented when their specific gravities were determined, equation (1) was used to adjust South Florida slash pine increment core specific gravity to tree specific gravity. The variables in this equation were associated with 77 percent of the variation about regression.

Equation (3) was developed for predicting the extracted increment core specific gravity from unextracted specific gravity and was associated with 59 percent of the variation in extracted increment core specific gravity.

A difference in average specific gravity was found between trees growing inland and those along the coast. Trees growing within 25 miles of the Atlantic or Gulf coasts had an average specific gravity of .639, while inland trees averaged .597. Data adjusted by analysis of covariance for age and d.b.h. indicated a significant difference in specific gravity between areas (.01 probability level).

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APPENDIX

Computational Procedures

1. Increment core specific gravity $= \dfrac{\text{ovendry weight of core}}{\text{green weight of core} - .3464\,(\text{ovendry weight of core})}$

2. Disk specific gravity $= \dfrac{\text{ovendry weight of disk}}{\text{displaced volume of disk}}$

3. Bolt specific gravity $= \dfrac{\text{specific gravity top disk} + \text{specific gravity bottom disk}}{2}$

4. Tree specific gravity $= \dfrac{\sum_{1-n} (\text{bolt volume} \times \text{bolt specific gravity})}{\sum_{1-n} \text{bolt volumes}}$

5. Bolt volume = bolt length, feet $\times \left[\dfrac{.005454\,(\text{d.i.b.})_t^2 + .005454\,(\text{d.i.b.})_b^2}{2}\right]$

   where: t = top of bolt
   b = base of bolt

6. (a) Mean core specific gravity $\bar{x} = \dfrac{\Sigma_i \Sigma_j X_{ij}}{m_1 n_1}$

   where: X_{ij} = the core specific gravity for the jth tree at the ith location
   m_1 = number of trees at each location
   n_1 = number of locations

   (b) The standard deviation of individuals was estimated from the sample range of the core specific gravities using the tabular values of the ratio of the standard deviation to the range.

7. Tree specific gravities were estimated from regression by:

   (a) Tree specific gravity $(Y) = b_0 + b_1 X_1 + b_2 X_2$

   where: Y = tree specific gravity
   X_1 = average specific gravity of 2 extracted cores
   X_2 = d.b.h./age

   (b) The standard error of the predicted mean tree specific gravity was estimated by--

$$S_{\hat{\bar{y}}} = \left[S^2_{y.x} \left(\frac{1}{m_2 n_2} + C_{11}(\bar{x}_{1,1} - \bar{x}_{1,2})^2 + C_{22}(\bar{x}_{2,1} - \bar{x}_{2,2})^2 + 2C_{12}(\bar{x}_{1,1} - \bar{x}_{1,2})(\bar{x}_{2,1} - \bar{x}_{2,2}) \right) + \frac{S^2_y}{m_1 n_1} \right]^{\frac{1}{2}}$$

   where: $S^2_{y.x}$ = residual mean squares
   S^2_y = variance of y prior to adjustment for regression
   $\bar{x}_{1,1}$ = mean core specific gravity of trees from which only cores were collected, sample (1)
   $\bar{x}_{1,2}$ = mean core specific gravity of trees collected for tree-core relationships, sample (2)
   $\bar{x}_{2,1}$ = mean d.b.h./age for sample (1)
   $\bar{x}_{2,2}$ = mean d.b.h./age for sample (2)
   m_1 = number of trees at each location, sample (1)
   m_2 = number of trees at each location, sample (2)
   n_1 = number of locations, sample (1)
   n_2 = number of locations, sample (2)

(c) The standard error of the core mean was approximated by the following computation when the variance were pooled to obtain the mean core specific gravity of more than one location:

$$\text{standard error} = \sqrt{\frac{K}{(\Sigma n_i)^2}\left(\frac{\Sigma S_i^2 + \bar{x}^2 \Sigma n_i^2 - 2\bar{x}\Sigma n_i S_i}{K-1}\right)}$$

where: K = the number of locations at which trees were bored for specific gravity

S_i = the sum of specific gravities of cores at the ith location ($= \Sigma_j X_{ij}$)

(d) When variances were not pooled the standard error of the mean was approximated by--

$$\text{standard error} = \frac{S}{\sqrt{n}}$$

where: S = standard deviation estimated from the sample range of core specific gravities

n = number of observations in sample

8. Percentage difference in specific gravity due to extraction $= \dfrac{\text{unextracted core sp. gr.} - \text{extracted core sp. gr.}}{\text{extracted core sp. gr.}} \times 100$

ida slash pine increment core/tree specific gravity relationships

Regression equations	r	r^2	Standard error
Tree specific gravity (Y):			
Y = 0.18589 + 0.80731 (sp. gr., outer 2/3 of 2 extracted cores) — 0.03267 (total height/age) — 0.00280 (d.b.h.)	0.91	0.83	0.020
Y = 0.16189 + 0.80396 (sp. gr., outer 2/3 of 2 extracted cores) — 0.03203 (total height/age)	0.90	0.81	0.022
Y = 0.18361 + 0.76856 (sp. gr., 2 extracted cores) — 0.14175 (d.b.h./age) + 0.62024 (1/age)	0.90	0.81	0.022
Y = 0.17283 + 0.83293 (weighted sp. gr., 2 extracted cores) — 0.12603 (d.b.h./age) — 0.00070 (total height)	0.90	0.81	0.023
Y = 0.19180 + 0.71603 (sp. gr., outer 2/3 of 2 cores) — 0.02878 (total height/age) — 0.00201 (d.b.h.)	0.90	0.81	0.022
Y = 0.17219 + 0.79316 (weighted sp. gr., 2 extracted cores) — 0.14593 (d.b.h./age)	0.89	0.79	0.022
Y = 0.16788 + 0.72376 (sp. gr., outer 2/3 of 2 cores) — 0.02810 (total height/age)	0.89	0.79	0.022
Y = 0.19570 + 0.73291 (weighted sp. gr., 2 cores) — 0.09789 (d.b.h./age) — 0.00107 (total height)	0.89	0.79	0.023
Y = 0.22179 + 0.69807 (sp. gr., outer 2/3 of 1 extracted core) — 0.05058 (total height/age) + 0.79707 (1/age)	0.89	0.79	0.023
Y = 0.23910 + 0.68818 (sp. gr., 2 extracted cores) — 0.10225 (d.b.h./age)	0.88	0.77	0.023
Y = 0.27541 + 0.66222 (sp. gr., 1 extracted core) — 0.07793 (d.b.h./age) — 0.00074 (total height)	0.88	0.77	0.023
Y = 0.21111 + 0.71795 (weighted sp. gr., 1 extracted core) — 0.04791 (total height/age) + 0.85262 (1/age)	0.88	0.77	0.023
Y = 0.27210 + 0.62504 (sp. gr., 1 extracted core) — 0.10203 (d.b.h./age)	0.87	0.76	0.024
Y = 0.20983 + 0.65672 (weighted sp. gr., 2 cores) — 0.13300 (d.b.h./age)	0.87	0.76	0.024
Y = 0.25570 + 0.65108 (weighted sp. gr., 1 extracted core) — 0.03097 (total height/age)	0.87	0.76	0.024
Y = 0.26108 + 0.63969 (sp. gr., outer 2/3 of 1 extracted core) — 0.03437 (total height/age)	0.87	0.76	0.024
Y = 0.23312 + 0.75253 (sp. gr., outer 1/3 of 2 extracted cores) — 0.05007 (total height/age) — 0.00234 (d.b.h.)	0.87	0.76	0.025
Y = 0.20834 + 0.75760 (sp. gr., outer 1/3 of 2 extracted cores) — 0.04953 (total height/age)	0.86	0.74	0.026
Y = 0.27471 + 0.58183 (sp. gr., 2 cores) — 0.04902 (merch. vol./age) — 0.00095 (total height)	0.86	0.74	0.026
Y = 0.13477 + 0.81722 (sp. gr., 2 extracted cores)	0.85	0.72	0.026
Y = 0.26009 + 0.55315 (sp. gr., 2 cores) — 0.07819 (merch. vol./age)	0.85	0.72	0.026
Y = 0.17213 + 0.74571 (sp. gr., 1 extracted core)	0.84	0.70	0.026
Y = 0.38677 + 0.45624 (sp. gr., 1 core) — 0.00149 (total height) — 0.07796 (d.b.h./age)	0.84	0.70	0.028
Y = 0.34502 + 0.47835 (sp. gr., outer 2/3 of 1 core) — 0.03175 (total height/age) — 0.00185 (d.b.h.)	0.84	0.70	0.027
Y = 0.32234 + 0.48636 (sp. gr., outer 2/3 of 1 core) — 0.03107 (total height/age)	0.83	0.69	0.028
Y = 0.22415 + 0.67812 (sp. gr., outer 1/3 of 2 cores) — 0.04885 (total height/age)	0.83	0.69	0.028
Y = 0.35651 + 0.47292 (weighted sp. gr., 1 core) — 0.03053 (total height/age) — 0.00285 (d.b.h.)	0.83	0.69	0.028
Y = 0.24605 + 0.66462 (sp. gr., outer 1/3 of 2 cores) — 0.04913 (total height/age) — 0.00143 (d.b.h.)	0.83	0.70	0.028
Y = 0.36048 + 0.52445 (sp. gr., outer 1/3 of 1 extracted core) — 0.04605 (total height/age) — 0.00208 (d.b.h.)	0.83	0.69	0.028
Y = 0.33248 + 0.53463 (sp. gr., 1 core) — 0.00197 (total height)	0.82	0.67	0.028
Y = 0.04217 + 0.84907 (sp. gr., outer 2/3 of 2 cores)	0.82	0.67	0.028
Y = 0.33666 + 0.53191 (sp. gr., outer 1/3 of 1 extracted core) — 0.04555 (total height/age)	0.82	0.67	0.029
Y = 0.33256 + 0.46931 (weighted sp. gr., 1 core) — 0.02994 (total height/age)	0.81	0.66	0.029
Y = 0.03454 + 0.94855 (weighted sp. gr., 2 extracted cores)	0.81	0.66	0.028
Y = 0.07528 + 0.80001 (weighted sp. gr., 2 cores)	0.80	0.64	0.029
Y = 0.03630 + 0.92853 (sp. gr., outer 2/3 of 2 extracted cores)	0.80	0.64	0.030
Y = 0.13743 + 0.76777 (weighted sp. gr., 1 extracted core)	0.77	0.59	0.031
Y = 0.24732 + 0.53899 (sp. gr., 2 cores)	0.76	0.58	0.032
Y = 0.14666 + 0.73850 (sp. gr., outer 2/3 of 1 extracted core)	0.75	0.56	0.032
Y = 0.42476 + 0.35615 (sp. gr., outer 1/3 of 1 core) — 0.04480 (total height/age)	0.74	0.55	0.034
Y = 0.44775 + 0.34399 (sp. gr., outer 1/3 of 1 core) — 0.04520 (total height/age) — 0.00162 (d.b.h.)	0.74	0.55	0.034
Y = 0.20608 + 0.58867 (sp. gr., outer 2/3 of 1 core)	0.73	0.53	0.033
Y = 0.29322 + 0.46297 (sp. gr., 1 core)	0.72	0.52	0.034
Y = 0.21344 + 0.57933 (weighted sp. gr., 1 core)	0.72	0.52	0.034
Y = 0.26642 + 0.52571 (sp. gr., outer 1/3 of 1 extracted core)	0.55	0.30	0.041
Y = 0.17509 + 0.67927 (sp. gr., outer 1/3 of 2 extracted cores)	0.55	0.30	0.041
Y = 0.18803 + 0.61142 (sp. gr., outer 1/3 of 2 cores)	0.52	0.27	0.042
Y = 0.34893 + 0.36082 (sp. gr., outer 1/3 of 1 core)	0.44	0.19	0.044

Clark, Alexander III, and Taras, Michael A.
1970. Wood Density Surveys of the Minor Species of Yellow Pine in the Eastern United States. Part VII--South Florida Slash Pine (Pinus elliottii var. densa Little & Dorman). Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-66, 11 pp.

South Florida slash pine (Pinus elliottii var. densa Little & Dorman) was sampled at 19 different locations over its entire range. Specific gravity was determined on increment cores in an unextracted and extracted condition. The average unextracted increment core specific gravity of the variety was .615, while the extracted increment core specific gravity was .547, a decrease of 12.43 percent. Increment core/tree specific gravity relationships were examined, and equations for predicting tree specific gravity from increment cores were developed. The average estimated tree specific gravity of the species was .580. The data show a significant geographical difference in specific gravity between inland and coastal trees. Trees from plots located within 25 miles of the Atlantic or Gulf coasts had significantly higher specific gravity than trees from inland plots.

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The Importance of Woody Twig Ends to Deer in the Southeast

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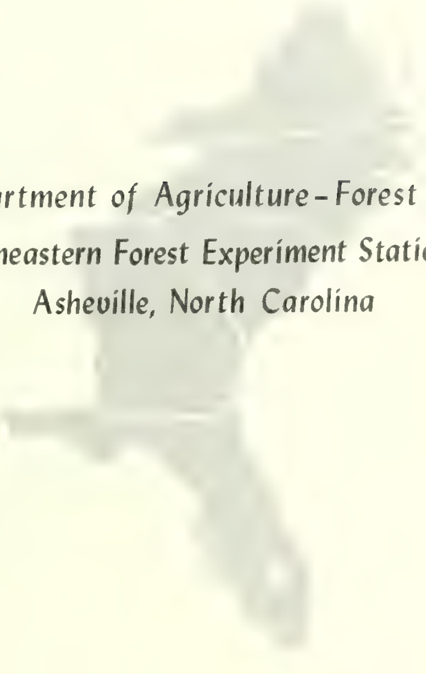

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The Importance of Woody Twig Ends to Deer in the Southeast

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INTRODUCTION

One of the basic assumptions underlying research on wildlife habitat in the five Atlantic states of the Southeast is that white-tailed deer (Odocoileus virginianus) rely heavily on the ends of woody twigs during the winter. Considerable research has been undertaken to determine methods for increasing and measuring the availability of woody twigs to deer. This study was conducted to determine the relative importance of woody twigs to deer in the Coastal Plain, Piedmont, Southern Appalachians, and the Ridge and Valley Province of the Southeast.

In earlier work, after analyzing 440 samples of deer rumina collected throughout the year in Missouri, Korschgen (1954) found that deer in that area rarely ate twigs. Dunkeson's (1955) observations of a tame deer in the Ozarks supported Korschgen's findings, as did Lay's (1964) in east Texas. Harlow (1961) analyzed 423 deer stomachs collected in Florida during the fall and winter. He found that, by volume, herbaceous matter contributed 11 percent, mast 40 percent, mushrooms

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9 percent, miscellaneous items 3 percent, and woody plant material--primarily evergreen leaves--37 percent to the diet. Ruff,[1] working in Pisgah National Forest in North Carolina, found that twigs accounted for only 5 percent of the total volume of 35 deer stomachs collected during the winter but that succulent twigs accounted for 40 percent of the volume of nine deer stomachs collected during the spring and summer.

Even in the Northeastern States where winters are longer and colder, evidence has been accumulating that deer may prefer foods other than twig ends during this season. Stiteler and Shaw (1966, p. 210) state, "The concept that browse is the principal food of white-tailed deer in the Northeast is open to serious question. Results of these surveys indicate that the use of woody twigs for food by white-tailed deer in the Northeast is inversely related to availability of other winter foods." Shaw and Ripley (1966) calculated that the percent, by weight, of twigs in deer's diet was 5.6 percent for three northern forests and 3.2 percent for three southern forests.

Our study, which relates the importance of woody twigs to other foods in four physiographic provinces of the Southeast, is tentative. We were not able to obtain large numbers of samples from each province during all seasons. Knowledge of the availability of food items in each location during the study period was not available.

METHODS

Personnel from the Southeastern Cooperative Wildlife Disease Study[2] made available rumen samples from deer killed in Alabama, Florida, Georgia, North Carolina, and South Carolina. During each of the four seasons, a 1-quart sample was taken from each of five deer collected in one night from a single location within each of the six states. Additional rumen samples were collected by the investigators and cooperators from road kills and deer killed during hunting seasons in Georgia, North Carolina, South Carolina, and Virginia.

During the 1-year study period, spring 1967 to spring 1968, 489 samples of the contents of deer rumina were collected and examined. Of this total, 34 were collected during the spring, 39 during the summer, 372 during the fall, and 44 during the winter season. All items retained in a 6.35 mm. sieve after washing were separated according to five plant parts: (a) fruit, (b) green leaves, (c) dead leaves, (d) succulent twigs and buds, and (e) hardened twigs and buds. These plant parts were identified as to species whenever possible. Unidentified items were categorized into 20 groups: green herbaceous stems and leaves, dried herbaceous stems and leaves, succulent green woody stems, hardened woody stems, dried deciduous leaves from woody plants, dried conifer needles, vines, fruit, green deciduous leaves from woody plants, green conifer needles, heath leaves, grasses, sedges, mushrooms, other fungi, insects, dead twigs, ferns, mollusks (snails), and other miscellaneous items.

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[1] Ruff, F. J. The white-tailed deer of the Pisgah National Game Preserve. 249 pp. 1938. (Unpublished mimeographed report on file at Southeast. Forest Exp. Sta., USDA Forest Serv., Blacksburg, Va.)

[2] These deer were collected under the direction of Dr. Frank Hayes, Director, Southeastern Cooperative Wildlife Disease Study, School of Veterinary Medicine, University of Georgia, Athens.

The data on each plant part were analyzed for frequency of occurrence and percent of the total volume. Additional items analyzed were physiographic province, season, and location. Because the condition of the vegetation varied from north to south, from east to west, and according to altitude, winter was considered to be that period between the first occurrence of 20° F. temperature and the last occurrence of 28° F. temperature at each location. Summer was considered to be the months of June, July, and August for all locations. Because certain plants were known to have differences in availability, the data were grouped according to the four major physiographic regions within the Southeast.

We recognized that rumen analysis has some disadvantages. For example, Norris (1943) found that, in sheep, difficult-to-digest food items such as twigs remained in the rumen for as long as 3 to 4 days before elimination. Similarly, Elliott (1967) supported Norris' conclusions; he suggested that, in ruminants, low protein roughages were slowly digested. Our rumen analyses were probably biased in favor of twigs or other coarse materials; conversely, soft fruits and mushrooms may have been digested very rapidly, resulting in a low-biased estimate of their importance.

RESULTS

Spring Season

No rumen samples were obtained from the Ridge and Valley Province for the spring or summer seasons. In the other physiographic regions, green succulent leaves and stems of both woody and herbaceous species dominated the top-ranking foods during the spring (table 1). Other important food items were the fruit of pricklypear and hawthorn in the Coastal Plain, flowers of yellow-poplar in the Southern Appalachians, mushrooms in the Coastal Plain and Piedmont, and acorns in the Southern Appalachians.

Summer Season

Materials from succulent green plants continued to dominate the ranking of foods taken by deer in the three provinces (table 2). Mushrooms appeared to reach a peak of importance, ranking first in the Piedmont, second in the Southern Appalachians, and third in the Coastal Plain. Fruit did not receive the use that was expected during this season. Possibly these foods were digested rapidly, leaving no evidence in the rumen, or our sample was too small, or there were only limited amounts of these items available. Fruit was important only in

Table 1.--Food items collected from 34 deer during the spring, by frequency and percentage of total volume

Southern Appalachians (11 samples)			Coastal Plain (13 samples)			Piedmont (10 samples)		
Item[1]	Frequency	Volume	Item[1]	Frequency	Volume	Item[1]	Frequency	Volume
	- - Percent - -			- - Percent - -			- - Percent - -	
Leaves (green)			Leaves (green)			Leaves (green)		
Woody spp.[2]	100.0	48.4	Woody spp.[2]	84.6	24.3	Herbaceous spp.[2]	100.0	59.7
Yellow-poplar	36.4	15.9	Herbaceous spp.[2]	46.2	22.1	Woody spp.[2]	90.0	34.2
Legumes[2]	27.3	12.4	Holly	15.4	10.4	Blackberry	30.0	.5
Herbaceous spp.[2]	36.4	11.7	Heath family	23.1	6.3	Greenbrier	20.0	.4
Sycamore	9.1	.3	Yellow-poplar	7.7	1.1	Honeysuckle	20.0	.1
Maple	36.4	.3				Plantain	10.0	.1
Subtotal		89.0	Subtotal		64.2	Subtotal		95.0
Fruit			Fruit			Twigs and stems		
Acorns[2]	27.3	4.1	Hawthorn	7.7	4.5	Woody, succulent[2]	70.0	4.7
Maple	9.1	.3	Pricklypear	7.7	1.6	Honeysuckle	10.0	.1
						Maple, succulent	10.0	.1
Subtotal		4.4	Subtotal		6.1	Subtotal		4.9
Twigs			Twigs			Mushrooms	10.1	.1
Woody, succulent[2]	63.6	2.8	Pine, succulent	7.7	14.9			
Rhododendron, succulent	9.1	.2	Woody, succulent[2]	61.5	10.4			
Subtotal		3.0	Subtotal		25.3			
Yellow-poplar flowers	63.6	3.4	Mushrooms	30.8	1.3			
Other items		.2	Other items		3.1			
Total		100.0	Total		100.0	Total		100.0

[1] Scientific names listed at end of Note.
[2] Unidentified.

Table 2.--Food items collected from 39 deer during the summer, by frequency and percentage of total volume

Southern Appalachians (12 samples)			Coastal Plain (16 samples)			Piedmont (11 samples)		
Item[1]	Frequency	Volume	Item[1]	Frequency	Volume	Item[1]	Frequency	Volume
	- - Percent - -			- - Percent - -			- - Percent - -	
Leaves (green)			Leaves (green)			Leaves (green)		
Woody spp.[2]	66.7	35.0	Woody spp.[2]	87.5	30.9	Woody spp.[2]	54.6	15.3
Herbaceous spp.[2]	25.0	21.3	Herbaceous spp.[2]	56.2	17.6	Herbaceous spp.[2]	45.5	10.5
Legumes[2]	41.7	5.8	Legumes[2]	31.3	9.7	Honeysuckle	54.6	4.3
Honeysuckle	8.3	3.7	Honeysuckle	18.8	5.5	Subtotal		30.1
Oak	33.3	2.0	Grape	6.2	1.6	Fruit		
Rhododendron	25.0	.8	Subtotal		65.3	Apple	54.6	6.4
Maple	41.7	.7	Twigs and stems			Blueberry	27.3	5.5
Subtotal		69.3	Woody, dead[2]	18.8	7.4	Oats	18.2	3.0
Acorns	16.7	.5	Woody, succulent[2]	43.7	3.9	Blackberry	36.4	2.4
Woody stems, dead	16.7	.7	Honeysuckle	18.8	3.1	Acorns	9.1	3.7
Mushrooms	83.3	28.0	Subtotal		14.4	Subtotal		21.0
Other items		1.5	Pecan (fruit)	12.5	1.9	Honeysuckle stems	45.5	5.[illegible]
			Mushrooms	75.0	11.9	Mushrooms	100.0	37.4
			Other items		6.5	Other items		5.9
Total		100.0	Total		100.0	Total		100.0

---

[1] Scientific names listed at end of Note.
[2] Unidentified.

the Piedmont. Acorns from the previous year continued to be important in the Piedmont and Southern Appalachians. For some unexplained reason, dead woody stems ranked within the top 10 food items in two provinces, but hardened live woody stems did not.

Fall Season

Acorns were by far the most abundant item found in deer rumina during the fall (table 3). Acorns ranked first in three of the four provinces and were second to Japanese honeysuckle in the Piedmont. Honeysuckle ranked high in every province except the Southern Appalachians, and it is probably second in importance to acorns during this season. Mushrooms and a variety of fruits such as grape, apple, pricklypear, sumac, blueberry, and honeylocust also ranked high. Leaves of woody species were frequently found in the samples, while woody twigs were notably absent.

Winter Season

Acorns continued to rank high in three of the four provinces (table 4). Grasses were important in two provinces. Japanese honeysuckle continued to rank high in all provinces, but it ranked first in only one, the Coastal Plain. Mushrooms continued to rank high in every province. Some fruits such as grape and sumac were taken in early winter. Rhododendron leaves dominated the samples from the Southern Appalachians. Succulent woody twigs appeared in the winter diet in the Coastal Plain, indicating that spring came earlier in this region during the sample year. Hardened woody twigs were not found in significant quantities in any sample.

DISCUSSION

An appraisal of the value of the various food items found in the samples appears below:

Fruits and Mast

Individual species of soft fruits may be limited in their period of availability, but, collectively, they are available almost year-round. Limited use was made of soft fruits during the spring and summer. Nevertheless, soft fruits should not be discounted. Because of their possibly high rate of digestibility, the limited sample size, or the limited availability, we may have underestimated their importance.

Acorns may rank high in the deer's diet every season of the year, depending upon the size of the acorn crop and the use made by other wildlife.

Table 3.--Food items collected from 372 deer during the fall, by frequency and percentage of total volume

Ridge-Valley (48 samples)		
Item[1]	Frequency	Volume
	- - Percent - -	
Leaves[2]		
Honeysuckle	25.0	2.8
Heath family	20.8	1.4
Subtotal		4.2
Fruit		
Acorns[3]	97.9	80.5
Hawthorn	8.3	1.5
Blueberry	16.7	1.0
Sumac	6.3	.8
Subtotal		83.8
Twigs and stems		
Herbaceous[3]	10.4	1.9
Legumes, succulent[3]	8.3	.7
Subtotal		2.6
Mushrooms	81.3	5.0
Grasses[3]	35.4	.7
Other items		3.7
Total		100.0

Southern Appalachians (15 samples)		
Item[1]	Frequency	Volume
	- - Percent - -	
Leaves[2]		
Rhododendron	33.3	9.3
Woody spp.[3]	40.0	2.8
Legumes[3]	46.7	2.5
Grape	20.0	1.8
Woody spp., dry[3]	46.7	1.0
Subtotal		17.4
Fruit		
Acorns[3]	86.7	67.1
Grape	60.0	8.2
Apple	13.3	1.0
Subtotal		76.3
Mushrooms	46.7	1.8
Grasses[3]	26.7	2.8
Other items		1.7
Total		100.0

Coastal Plain (188 samples)		
Item[1]	Frequency	Volume
	- - Percent - -	
Leaves[2]		
Honeysuckle	63.8	7.9
Unidentified	14.9	1.1
Subtotal		9.0
Fruit		
Acorns[3]	93.1	73.5
Sumac	27.1	2.0
Hawthorn	9.6	.8
Legumes	8.5	.6
Subtotal		76.9
Stems		
Herbaceous[3]	44.2	4.1
Fleshy pricklypear	16.0	1.7
Subtotal		5.8
Mushrooms	64.4	2.2
Grasses[3]	25.0	.6
Other items		5.5
Total		100.0

Piedmont (121 samples)		
Item[1]	Frequency	Volume
	- - Percent - -	
Leaves[2]		
Honeysuckle	85.9	38.4
Grape	21.5	1.7
Greenbrier	32.2	1.6
Woody spp.[3]	19.8	1.3
Honeylocust	19.8	1.3
Subtotal		44.3
Fruit		
Acorns[3]	43.8	24.0
Corn	4.1	6.2
Sumac	27.3	3.3
Subtotal		33.5
Herbaceous stems[3]	82.6	15.1
Mushrooms	76.9	4.2
Other items		2.9
Total		100.0

---

[1] Scientific names listed at end of Note.
[2] Leaves are green unless otherwise noted.
[3] Unidentified.

Table 4.--Food items collected during the winter, by frequency and percentage of total volume

Ridge-Valley (5 samples)			Southern Appalachians (13 samples)			Coastal Plain (12 samples)			Piedmont (14 samples)		
Item[1]	Frequency	Volume	Item[1]	Frequency	Volume	Item[1]	Frequency	Volume	Item[1]	Frequency	Volume
	- - Percent - -			- - Percent - -			- - Percent - -			- - Percent - -	
Leaves[2]			Leaves[2]			Leaves[2]			Leaves[2]		
Honeysuckle	60.0	19.0	Rhododendron	100.0	78.0	Honeysuckle	75.0	88.9	Herbaceous spp.[3]	21.4	14.4
Grape	40.0	6.0	Honeysuckle	7.7	2.7	Holly	16.7	.5	Woody spp., dry[3]	64.3	3.2
Legumes[3]	40.0	1.2	Galax	46.2	1.2	Oak	50.0	.3	Grape	14.2	2.1
Woody spp., dry[3]	20.0	.7	Mountain-laurel	7.7	.7	Woody spp.[3]	8.3	.2	Honeysuckle	28.6	1.1
Subtotal		26.9	Woody spp., dry[3]	53.9	.5	Subtotal		89.9	Greenbrier	35.7	.9
Fruit			Grape	7.7	.4	Fruit			Woody spp.[3]	21.4	.6
Acorns[3]	60.0	27.3	Greenbrier	7.7	.4	Sumac	41.7	1.6	Subtotal		22.3
Hawthorn	20.0	2.3	Subtotal		83.9	Greenbrier	16.7	.2	Acorns[3]	14.2	.9
Apple	20.0	.4	Fruit			Subtotal		1.8	Honeysuckle stems	7.1	.2
Persimmon	40.0	.3	Acorns[3]	30.8	6.6	Stems and twigs			Mushrooms	35.7	1.2
Subtotal		30.3	Grape	15.4	4.1	Fleshy pricklypear	25.0	4.7	Grasses[3]	42.8	74.6
Honeysuckle stems	40.0	8.8	Apple	7.7	3.3	Woody spp., succulent[3]	16.7	.6	Other items		.8
Mushrooms	40.0	.3	Subtotal		14.0	Honeysuckle	25.0	.1			
Grasses[3]	40.0	33.6	Mushrooms	53.8	1.1	Pine	8.3	.1			
Other items		.1	Other items		1.0	Subtotal		5.5			
						Mushrooms	50.0	2.4			
						Other items		.4			
Total		100.0	Total		100.0	Total		100.0	Total		100.0

[1] Scientific names listed at end of Note.
[2] All leaves are green unless otherwise noted.
[3] Unidentified.

Mushrooms

Mushrooms ranked within the top 10 foods in every province during every season, with only one exception. Their use seems to be least in the spring, perhaps because of low availability at this time, and highest during the summer.

Green Leaves from Woody Plants, Forbs, and Grasses

"If it's green, it's eaten" seems to be a suitable generality. Materials from fast-growing green plants were the major items found in those deer stomachs examined during the spring and summer months. It appears that anything which stays green throughout the winter has importance as food for deer.

Japanese honeysuckle was one of the most important producers of green winter food in the Southeast. Rhododendron in the Southern Appalachians and grass in the Piedmont and in the Ridge and Valley Province were important deer foods during winter.

Woody Twigs

Twigs were an important food item in all provinces during the spring. At this time, growing twigs are so succulent they could be classed as herbaceous in texture rather than woody. Hardened twigs did not occur in as much as ½ of 1 percent of the food in our fall-winter sample of 416 deer. This low occurrence was noted in spite of the fact that woody twigs are more difficult to digest and remain in the rumen longer than other foods.

The following additional observations in North Carolina and Virginia contributed to our questioning the importance of woody twigs:

(a) In the mountain cove-hardwood region surrounding Curtis Creek in western North Carolina, 182 acres were clearcut; approximately ½ ton of woody twigs was produced per acre during the year after cutting. Deer activity in these cuttings increased, but an analysis of 23 rumen samples collected during the third winter after cutting revealed that twigs occurred in small amounts in only 13 percent of the stomachs (table 5).

(b) A 2,322-acre enclosure at Dublin, Virginia, contains over 300 deer thriving on a range containing very little woody vegetation.

(c) Herd size remains low in an experimental 7,500-acre area in the Jefferson National Forest, Virginia, in spite of the fact that an abundance of twigs has been provided during 8 years of intensive cutting.

Table 5.--Analysis of 1-quart samples of the contents of 23 deer stomachs collected at Curtis Creek, North Carolina, on December 16 and 17, 1966

Item[1]	Frequency	Volume[2]
	- - - Percent - - -	
Leaves		
Rhododendron	100.0	27.0
Deciduous hardwood, dried[3]	82.6	9.0
Galax	73.9	8.0
Herbaceous spp.[3]	52.1	2.0
Mountain-laurel	4.3	2.0
Evergreen hardwood[3]	26.1	.4
Christmas fern	26.1	.4
Blackberry	8.7	.2
Greenbrier	8.7	.1
Ebony spleenwort	4.3	.1
Subtotal		49.2
Fruit		
Acorns[3]	26.1	13.0
Scarlet oak acorns	21.7	12.0
Red oak acorns	17.4	11.0
Chestnut oak acorns	4.3	1.0
Subtotal		37.0
Fungi		
Ascomycetes	39.1	4.0
Polyporus versicolor	26.1	3.0
Lichen	21.7	1.0
Agaricales	17.4	1.0
Subtotal		9.0
Grass[3]	43.4	2.4
Twig ends		
Woody, hardened[3]	13.0	.9
Miscellaneous		
Buds, stems, acorns, leaves, sprouts[3]	13.0	1.5
Total		100.0

[1] Scientific names listed at end of Note.
[2] Ocular estimate.
[3] Unidentified.

CONCLUSION

Twigs have been considered important in the Southeast in the past, but we suspect that this conclusion was reached mainly through examination of the plant and not of the deer itself. We concluded from analysis of 489 samples of deer rumina that virtually all browsing of twigs takes place during the spring and summer seasons, when this part of the plant is growing rapidly and is succulent.

It is quite clear that research and management in the Southeast should recognize all possible sources of food for white-tailed deer when attempting to determine the carrying capacity of deer range.

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FOOD ITEM LIST

Common name	Scientific name
Acorns	*Quercus* spp.
Apple	*Malus* spp.
Blackberry	*Rubus* spp.
Blueberry	*Vaccinium* spp.
Chestnut oak	*Quercus montana* Willd.
Christmas fern	*Polystichum acrostichoides* (Michx.) Schott
Corn	*Zea mays* L.
Ebony spleenwort	*Asplenium platyneuron* L.
Fungi (mushrooms & other)	Ascomycetes
	Basidiomycetes
	Agaricales
	Polyporus versicolor
Galax	*Galax aphylla* L.
Grape	*Vitis* spp.
Greenbrier	*Smilax* spp.
Hawthorn	*Crataegus* spp.
Holly	*Ilex opaca* Ait.
Honeylocust	*Gleditsia triacanthos* L.
Japanese honeysuckle	*Lonicera japonica* Thunb.
Legume	
Maple	*Acer* spp.
Mountain-laurel	*Kalmia latifolia* L.
Oats	*Avena sativa* L.
Pecan	*Carya* spp.
Persimmon	*Diospyros virginiana* L.
Pine	*Pinus* spp.
Plantain	*Plantago lanceolata* L.
Pricklypear	*Opuntia humifusa* Raf.
Red oak	*Quercus rubra* L.
Rhododendron	*Rhododendron maximum* L.
Scarlet oak	*Quercus coccinea* Muenchh.
Shining sumac	*Rhus copallina* L.
Sycamore	*Platanus occidentalis* L.
Yellow-poplar	*Liriodendron tulipifera* L.
Miscellaneous	
Heath	Ericaceae

Cushwa, Charles T., Downing, Robert L., Harlow, Richard F.,
and Urbston, David F.
1970. The Importance of Woody Twig Ends to Deer in the Southeast. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-67, 12 pp.

Year-round samples of 489 deer rumina from six Southeastern States were analyzed to determine the relative importance of various types of foods. Green material, fruits, mast, and mushrooms were all important foods at every season of the year. The least important food was woody twigs, which did not occur in as much as $\frac{1}{2}$ of 1 percent of the food in the fall-winter sample of 416 deer. Virtually all browsing of twigs takes place during the spring and summer, when this part of the plant is succulent. Future habitat research and management in the Southeast should recognize all possible sources of food for deer, not just the woody component.

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BUDJ--FORTRAN-4 PROGRAM

for budgeting cost of each employee by funds chargeable and cost schedules applicable during each pay period

by

L. R. Grosenbaugh

U.S. Department of Agriculture-Forest Service
Southeastern Forest Experiment Station
Asheville, North Carolina

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U.S.FOREST SERVICE RESEARCH PAPER SE-68. (ORIGINAL VERSION DATED 7-21-69)
SOUTHEASTERN FOREST AND RANGE EXPERIMENT STATION, ASHEVILLE, N.C.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

BUDJ -- FORTRAN-4 PROGRAM FOR BUDGETING COST OF EACH EMPLOYEE BY FUNDS CHARGEABLE AND COST SCHEDULES APPLICABLE DURING EACH PAY PERIOD

L. R. GROSENBAUGH

SUMMARY

Annual cost-to-employer for a permanent or part-time employee may be specified by a set of indices referring to applicable salary or wage table, grade, step, and pay period when step-increase will become effective (if any). Cost-to-employer of fringe benefits such as life insurance, health insurance, retirement, and uniform or other allowance can be specified by additional indices in the set that may depend upon (or be independent of) salary or wage indices.

As many as 3 versions of cost tables for these various items (including both 'GS' annual salary tables and 'WB' hourly wage rates) may be specified within each fiscal year, together with another table which shows version of each cost table that is effective for each of 27 pay periods.

In addition to index cards characterizing each employee, budget cards for each must be prepared, showing fund, cost account, or appropriation to which each pay period of that employee is expected to be charged. If desired, an employee's cost for a 10-day pay period may be spread among several cost accounts or appropriations.

'BUDJ' will run on any large scientific computer with USASI Fortran compiler and at least 32K words of memory (word length must be at least 32 bits). Cost per run should not exceed one dollar per 200 employees, and two runs will give cost (by appropriation) attributable to any increase in pay or fringe benefit. Numerous options for computing and printing out additional information are available.

The author is Chief Mensurationist, Pioneering Research Unit - Timber Measurement, Forest Service, SDA, Atlanta, Georgia.

================================== GENERAL =====================================

Budgeting annual cost-to-employer for all employees is complicated by such unforeseen events as unanticipated promotions, change in salary or wage schedules, change in cost of fringe benefits, resignations, recruitment, and change in employee's election of optional elements in fringe-benefit plans.

Furthermore, automatic or planned step-increases (government employees first became eligible for them under the Ramspeck Act) and periodic changes in biweekly hours worked by less-than-full-time employees cause much laborious computation, even though they may be anticipated at the beginning of the year.

Finally, a serious additional burden is imposed on budgeting officers when promotions are made effective other than at the end of a payperiod, or when costs of an employee for a single pay period are charged to several different funds.

Obviously, a high-speed computer would be the most efficient way to handle the job. However, existing payroll programs tend to be extremely costly and are usually run on inefficient computers which lack the capability to make frequent runs cheaply -- a capability especially needed by budget officers near the end of the fiscal year.

The author was confident at the outset that his Fortran-4 accounting program 'ACX' could be easily adapted to the job. Although this was true, expensive and time-consuming sorts were required for hundreds of employees, each budgeted for 27 pay periods and frequently charged to more than one cost account or appropriation.

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==================== ESTABLISHING NECESSARY COST TABLES ====================

Although the original program is designed to handle U.S. Government employees (specifically those of the Forest Service in the Department of Agriculture), minor revision (primarily in dimensioning, indexing, and range of indices permitted) will adapt it to use by other public or private agencies.

Six cost tables must be established by data statement in block data subprogram 'BLBJ' prior to compilation. Each cost table may have an original version and 2 updates during the fiscal year. Storage space reserved for the updated versions is initialized to zero until the update is inserted into the compilation.

Appendix A shows an original version of each of the 6 tables, and an update of the first one. The original version of the 10-step, 18-grade 'GS' table of annual salary in dollars is inserted as 'J1J'. It was specified by Executive Order 11413 of 6-11-68 under 5 USC 5332(A) and was effective only for the first (partial) pay period of fiscal year 1970. The first update of this table is inserted as 'J2J', specified by Executive Order 11474 of 6-16-69 under the same statute effective for the second and all subsequent pay periods.

The original version of the 9-step, 11-grade 'WB' table of hourly wages in cents per hour is inserted as 'K1K'. It was specified by Notice FS8-33-68 of 7-18-68. Note that WB steps 4, 5, 6 correspond to WL steps 1, 2, 3, and that WB steps 7, 8, 9 correspond to WS steps 1, 2, 3.

Four fringe benefits each currently involve only an original table (life insurance, health insurance, retirement, and uniform allowance), although Congress did subsequently modify several of them.

The amount of Government-subsidized life insurance cost (FEGLI) is computed by truncating annual earnings to whole thousands of dollars, adding 3000 dollars, increasing to 10,000 dollars if less, truncating to 45,000 dollars if more. Government contribution each pay period is at the rate of .1375 dollars per thousand dollars of insurance, as specified by 5 USC 8707. The constants 3, 10, 45, and 1375 are inserted as 'L1L'.

Government cost for health insurance is either 410 cents or 168 cents per pay period, depending on whether the employee elects high or low 'FEHBA' benefits, as specified by 5 USC 8906. These constants are inserted as 'M1M'.

Government cost for retirement depends on whether retirement for a given employee is under Civil Service or Social Security plans. The former cost was originally computed as 6.5 percent of gross salary per pay period as specified by 5 USC 8334. The latter is set by the current version of the Social Security Act at 4.8 percent. In the latter case, the Government's contribution can never exceed $14.40. Although there is no similar restriction for Civil Service Retirement, a fictitious limit of $200.00 (higher than any CS salary could currently generate) has been set to allow both retirements to be computed by a single algorithm. Retirement constants are inserted as 'N1N'.

================================ GENERAL ================================

Budgeting annual cost-to-employer for all employees is complicated by such unforeseen events as unanticipated promotions, change in salary or wage schedules, change in cost of fringe benefits, resignations, recruitment, and change in employee's election of optional elements in fringe-benefit plans.

Furthermore, automatic or planned step-increases (government employees first became eligible for them under the Ramspeck Act) and periodic changes in biweekly hours worked by less-than-full-time employees cause much laborious computation, even though they may be anticipated at the beginning of the year.

Finally, a serious additional burden is imposed on budgeting officers when promotions are made effective other than at the end of a payperiod, or when costs of an employee for a single pay period are charged to several different funds.

Obviously, a high-speed computer would be the most efficient way to handle the job. However, existing payroll programs tend to be extremely costly and are usually run on inefficient computers which lack the capability to make frequent runs cheaply -- a capability especially needed by budget officers near the end of the fiscal year.

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In Region 8 of the U.S. Forest Service, there are currently 4 levels of annual uniform allowance -- \$72.00, \$102.00, \$78.00, \$108.00 and these (in cents) have been inserted as 'I1N'. In addition, because of complicated stipulations, any arbitrary intermediate amount may be punched in a special field on an index card where the uniform index is shown as 5.

Needless to say, when the index for any fringe benefit is shown as zero, it implies that there is no cost-to-employer for that particular benefit in the case of the employee indexed zero.

Before leaving the subject of cost-tables established in block data subprogram 'BLBJ', several other points should be explained.

27 pay periods must always be provided for, even though the 1st and 27th commonly have less than 10 days each. Rarely, a 10-day 1st period and a zero-day 27th period may occur. The matrix JN is dimensioned (27,6), which can be interpreted as implying that it has 6 rows of 27 cells each. Each row specifies the effective version (1, 2, or 3) of each of the 6 tables discussed above (in the order discussed) on the pay period denoted by the cell in which the version digit occurs. Appendix D (page 34) shows how JN looks when initialized as specified in Appendix A. Thus initialized, JN will cause version 1 of the "GS' salary table to be used in the first (partial) pay period of FY 70 and will cause version 2 to be used for the next 26 pay periods. Versions 1 of the 5 remaining tables will be used for all 27 pay periods.

Although it is obvious that table JN must be appropriately changed when new versions of the 6 tables are inserted, it can also be changed to ignore any updates already inserted. This is particularly helpful in getting cost of increases occasioned by changes in the cost tables (due to legislation, administrative fiat, etc.).

Ordinarily, the user will not have to concern himself with other constants in 'BLBJ' except to set MRE, MPR, MPU, JW, JX, and MEOF on card BLBJ 21 to integers appropriate to the computer installation he is using. They should usually be integers appropriate to system input stream, system print unit, system punch unit, 2 scratch tapes, and zero (if MPR is equated to system print). If, however, the user is adapting the program to tables of different size, and if 'GS' and 'WB' tables are related by scale factors different from those suitable to dollars per year and cents per hour, then KN and LK must be initialized differently.

INPUT

After block data subprogram 'BLBJ' has been initialized appropriately, program 'BUDJ' can be executed when supplied with valid input data.

Appendix B illustrates the format needed by cards to be input to the program as well as the format of a card output for use with accounting program 'ACX'.

The first element of input must be a control card. It will be the only element of input if the optional printout of 80-hour salary tables is the only output desired (the 'ZERO' option is discussed below).

A control card must have its first four columns blank, and uses the next forty spaces for alphameric identification of the particular run being made. The date of the final Saturday in the current payperiod should be shown in the next field, and the next field can be left blank or can contain any positive or negative integer in its columns. This is available to the user for run identification, or to pass some parameter to optional subroutines 'PERS' and 'REPT', discussed later.

The next 2-digit field is for the positional number of the current pay period in the set of 27 that makes up a fiscal year. The next 2-digit field is for the last two digits of the fiscal year. Two 2-digit fields follow, containing the number of potential work days in the 1st and the 27th pay periods. These can vary between 0 and 10, but their sum must be 10, 11, or 12.

A field of six 1-digit numbers follows, and it will be blank except when a printout of 80-hour cost-to-employer tables is desired. In that case, the first five columns of the field must each contain the digit 1, 2, or 3, indicating the version of each of the first five cost tables that is to be printed out. These tables will be given the date punched on the control card, whether that date is appropriate or not to the versions specified. No printout will occur if any of the first five columns of the field lacks a 1, 2, or 3. The sixth column of the field should be left blank, since it is currently ignored on input.

The last column of a control card is used to specify which of 10 possible optional paths the user desires the program to follow. These options are described on page 17 of appendix B. 'ZERO' or 'BLANK' specifies that no input data follows, and its only result will be printout of cost tables specified in the next to last field. 'ONE' calls only for checking or editing of index cards, whereas 'TWO' calls only for checking or editing of budget cards.

Digits 3-9 call for standard printout of cost by appropriation if no errors are found, plus certain other punching or optional calls to subroutines 'PERS' and 'REPT', described more fully in Appendix B and later in this text. It should be noted that a printout of cost tables can be specified regardless of whatever option may appear in column 80.

Any option but 'ZERO' (or 'BLANK') results in printing error diagnostic messages when erroneous or inconsistent data input cards are found.

A control card with a nonzero option must be followed directly by the first index card of the first employee. Format and content of this card are shown in Figure 2 of Appendix B. The first index card of each employee must contain an asterisk in column 10.

No matter how many index cards are needed to characterize an employee's cost during the fiscal year, the last such card must be blank in columns 75, 77, and 78. The first such index card for a given employee must have an asterisk in column 10 and should reflect index information that characterizes the employee on July 1 at the start of the fiscal year.

Index card or cards for first employee must be followed by his budget cards, of which there must be at least 2, since 27 10-day payperiods must be accounted for. Format and content of this card are shown in Figure 3 of Appendix B. First or last pay periods cannot be charged to more than one cost account or appropriation. The appropriation '-1' denotes nonpay status for some or all of a pay period -- because of LWOP, scheduled nonwork days, or the fact that the employee was not employed by the budgeting organization at that time, though possibly employed by the agency elsewhere in some differently budgeted branch of the agency. Blank (or zero) days following a nonzero appropriation imply a full pay period of 10 potential workdays.

A full fiscal year must be budgeted for each employee, though the actual number of days in the first and last pay period will automatically replace whatever days appear on budget card. If an employee is not expected to work an average of 80 hours per 10-day pay period, a lesser number should be specified in columns 51 and 52 of his current index card. Chargeable hours will be additionally reduced by the program if less than 10 days are budgeted in a pay period.

The last budget card for each employee must contain in columns 77-78 a positive nonzero integer denoting the fund to which uniform allowance would be charged, whether or not the employee is actually entitled to such allowance (his index will determine entitlement).

Errors or inconsistencies in punching are described in Appendix E, using the Fortran-4 abbreviations '.NE.' for 'NOT EQUAL TO', '.GT.' for 'GREATER THA '.LE.' for 'LESS THAN OR EQUAL TO', etc. Some of the inconsistencies are peculiar to the governmental pay system (such as no step increases for WB employees) and would have to be reviewed carefully if the program were to be modified for use by a private agency.

A separator card (see Figure 4 of Appendix B) must follow the last budget card of the last employee. It may be followed by unsorted brought-forward car (see Figure 5 of Appendix B) if these are desired. They may be prepared from payroll summaries or can be automatically produced by the previous run of 'BUDJ'. Unplanned overtime can be inserted by this mechanism if desired. The last brought-forward card (or the first separator card if there are no brought forward cards) must be followed by another separator card.

This second separator card can be followed either by a control card and data input for an additional job, or by a program-end card.

Page 30 of Appendix C gives a listing of valid input for a small example. A listing of 3 inputs that are invalid for specified reasons is also given in Appendix E, along with the code used in error messages.

Deck arrangements, modifications needed, and system control cards needed by Univac 1108, RCA Spectra 70, IBM 360, IBM 7094-7044, and CDC 6400-6600 are shown in Appendix C.

OPTIONAL OUTPUT

After each individual employee has been completely processed and all pertinent data aggregated for the standard report, there is considerable additional information available about that employee, but it will be wiped out when the first card for the next employee is read.

However, by specifying options 7, 8, or 9 in column 80 of the control card, the user will ensure that subroutine 'PERS' (now a dummy) be called before the information is wiped out. The subroutine has access to 'labelled common' where all important information is stored, and the user can easily expand the dummy to test certain quantities and extract desired information. The information may be aggregated if desired, and/or written on tapes JW and/or JX. After all employees have been processed and the standard summary and check printed out, the 7, 8, 9 options also ensure that subroutine 'REPT' (now a dummy) be called.

The user can easily expand 'REPT' so that it rewinds his tapes and reads them to print out additional data in the desired form. Although the user could avoid using scratch tapes by printing the information intermingled with current pay period data, such procedure outputs messier and less useful reports.

A number of aids have been built into the main program to aid the user in exploiting this option.

LOP(6) contains the secondary subscript appropriate for the latest index vector 'IC'. Depending on what subroutine 'PERS' has been programmed to write, a single version of subroutine 'REPT' may be programmed to print one or two special reports in addition to the standard report. If the system possesses subroutine sort/merge capability, tapes JW and/or JX can be sorted by grade, step, and name of employee before printing (instead of being printed in the sequence in which employees were input). Some examples of the sort of information obtainable in special reports are latest index information for all employees, uniform allowance information only for those employees entitled to uniform allowance, Ramspeck dates and step-increase only for those scheduled for step-increases, names of those stipulated to work regularly less than 80 hours per pay period, etc.

The 29-cell vector 'JC' contains gross cost for a given employee for each pay period starting with the current one. His uniform allowance (if any) is in JC(28), and JC(29) sums all preceding cells.

The other major source of information is a matrix 'MZ' with 4 rows extending for 199-cells each. This limits the number of split charges that can be budgeted for an employee to 198 out of a maximum of 260-262 if each day were charged separately. The first row of this matrix contains the two-digit appropriation number, the second row contains the correct number of days charge to that appropriation in that pay period (1-10), and the third row contains the position or sequence (1-27) within fiscal year for the pay period when the char was made.

Matrix MZ's first 3 rows have primary subscripts running from 1 to KPP. The current pay period has subscripts running from KPI to KPII. The fourth row contains the cost in cents of the charges in the cells above it. No valid costs have been computed for fourth-row cells running from 1 to (KPI-1), which are pay periods prior to the current one.

The 27th pay period ends in cell (KPP-1). The four cells denoted by KPP involve appropriation to which uniform is charged, the digit 10, the digit 28, and the amount of uniform allowance in cents.

Thus, MZ(KPI,1) contains the appropriation (an integer) for the first charge in the current pay period, and MZ(KPI,4) contains the amount of the charge in cents.

The user will find that KPAGE has been initialized to 1, and KLINE to 60, so that if he wishes to paginate in 'PERS' using these parameters, he is not plagued by the difficulty of initializing in a repetitively called subroutine. He will also find that if he wishes to print appropriation preceded by the terminal digit of fiscal year, he need only add MZ(I,1) to MFY. Finally, he will find that IY(7) through IY(10) have been set to zero and are available to 'PERS' as accumulators.

```
================================= APPENDIX A ===================================

       TABLES AND CONSTANTS THAT MUST BE ESTABLISHED BY DATA STATEMENTS
             IN BLOCK DATA SUBPROGRAM 'BLBJ' PRIOR TO COMPILATION
                       (SEE PAGES 3-4 FOR DISCUSSION)

================================================================================
```

PERTINENT EXCERPTS FROM BLOCK DATA SUBPROGRAM 'BLBJ'

```
 DATA MRE/ 5/,MPR/ 6/,MPU/ 1/,JW/ 4/,JX/ 8/,MEOF/0/                     BLBJ  21
ODATA LANK/1H /,LPLUS/1H+/,LASK/1H*/,LMIN/1H-/,LEQU/1H=/,               BLBJ  22
1LAST/3H999/                                                            BLBJ  23
 DATA IZERO/0/,LAS9/999999999/,JGS/2HGS/,JWB/2HWB/                      BLBJ  24
ODATA J1J/                                                              BLBJ  25
1 3889, 4019, 4149, 4279, 4408, 4538, 4668, 4798, 4928, 5057,           BLBJ
2 4231, 4372, 4513, 4655, 4796, 4937, 5078, 5219, 5360, 5501,           BLBJ
3 4600, 4753, 4907, 5060, 5214, 5367, 5521, 5674, 5828, 5981,           BLBJ
4 5145, 5316, 5487, 5658, 5829, 6000, 6171, 6342, 6513, 6684,           BLBJ
5 5732, 5924, 6115, 6307, 6498, 6690, 6881, 7073, 7265, 7456,           BLBJ
6 6321, 6532, 6743, 6955, 7166, 7377, 7588, 7799, 8010, 8221,           BLBJ
7 6981, 7214, 7447, 7680, 7913, 8146, 8379, 8612, 8845, 9078,           BLBJ
8 7699, 7956, 8213, 8470, 8727, 8984, 9241, 9498, 9755,10012,           BLBJ
9 8462, 8744, 9026, 9308, 9590, 9872,10154,10436,10718,11000,           BLBJ
A 9297, 9607, 9917,10227,10537,10847,11157,11467,11777,12087,           BLBJ
B10203,10543,10883,11223,11563,11903,12243,12583,12923,13263,           BLBJ
C12174,12580,12986,13392,13798,14204,14610,15016,15422,15828,           BLBJ
D14409,14889,15369,15849,16329,16809,17289,17769,18249,18729,           BLBJ
E16946,17511,18076,18641,19206,19771,20336,20901,21466,22031,           BLBJ
F19780,20439,21098,21757,22416,23075,23734,24393,25052,25711,           BLBJ
G22835,23596,24357,25118,25879,26640,27401,28162,28923,28923,           BLBJ
H26264,27139,28014,28889,29764,29764,29764,29764,29764,29764,           BLBJ
I30239,30239,30239,30239,30239,30239,30239,30239,30239,30239/           BLBJ
ODATA J2J/                                                              BLBJ  26
1 3889, 4019, 4149, 4279, 4408, 4538, 4668, 4798, 4928, 5057,           BLBJ
2 4360, 4505, 4650, 4795, 4940, 5085, 5230, 5375, 5520, 5665,           BLBJ
3 4917, 5081, 5245, 5409, 5573, 5737, 5901, 6065, 6229, 6393,           BLBJ
4 5522, 5706, 5890, 6074, 6258, 6442, 6626, 6810, 6994, 7178,           BLBJ
5 6176, 6382, 6588, 6794, 7000, 7206, 7412, 7618, 7824, 8030,           BLBJ
6 6882, 7111, 7340, 7569, 7798, 8027, 8256, 8485, 8714, 8943,           BLBJ
7 7639, 7894, 8149, 8404, 8659, 8914, 9169, 9424, 9679, 9934,           BLBJ
8 8449, 8731, 9013, 9295, 9577, 9859,10141,10423,10705,10987,           BLBJ
9 9320, 9631, 9942,10253,10564,10875,11186,11497,11808,12119,           BLBJ
A10252,10594,10936,11278,11620,11962,12304,12646,12988,13330,           BLBJ
B11233,11607,11981,12355,12729,13103,13477,13851,14225,14599,           BLBJ
C13389,13835,14281,14727,15173,15619,16065,16511,16957,17403,           BLBJ
D15812,16339,16866,17393,17920,18447,18974,19501,20028,20555,           BLBJ
E18531,19149,19767,20385,21003,21621,22239,22857,23475,24093,           BLBJ
F21589,22309,23029,23749,24469,25189,25909,26629,27349,28069,           BLBJ
G25044,25879,26714,27549,28384,29219,30054,30889,31724,31724,           BLBJ
H28976,29942,30908,31874,32840,32840,32840,32840,32840,32840,           BLBJ
I33495,33495,33495,33495,33495,33495,33495,33495,33495,33495/           BLBJ
ODATA J3J/                                                              BLBJ  27
1180*0/                                                                 BLBJ
```

(CONTINUED ON NEXT PAGE)

(CONTINUATION FROM PRECEDING PAGE)

```
     ODATA K1K/                                                          BLBJ  28
     1199,209,219,219,230,242,285,300,315,                               BLBJ
     2211,222,233,232,244,256,309,325,341,                               BLBJ
     3222,234,246,244,257,270,333,350,368,                               BLBJ
     4235,247,259,258,272,286,352,371,390,                               BLBJ
     5246,259,272,271,285,299,372,392,412,                               BLBJ
     6266,280,294,293,308,323,392,413,434,                               BLBJ
     7286,301,316,314,331,348,412,434,456,                               BLBJ
     8306,322,338,336,354,372,432,455,478,                               BLBJ
     9326,343,360,358,377,396,449,473,497,                               BLBJ
     A346,364,382,380,400,420,476,501,526,                               BLBJ
     B359,378,397,395,416,437,503,529,555/                               BLBJ
     ODATA K2K/                                                          BLBJ  29
     199*0/                                                              BLBJ
     ODATA K3K/                                                          BLBJ  30
     199*0/                                                              BLBJ
      DATA L1L/3,10,45,1375/,L2L/4*0/,L3L/4*0/                           BLBJ  31
      DATA M1M/410,168/,M2M/0,0/,M3M/0,0/                                BLBJ  32
      DATA N1N/65,48,20000,1440/,N2N/4*0/,N3N/4*0/                       BLBJ  33
      DATA I1N/7200,10200,7800,12500/,I2N/4*0/,I3N/4*0/                  BLBJ  34
      DATA JN/1,26*2,27*1,27*1,27*1,27*1,27*1/                           BLBJ  35
      DATA KN/1000,1,1000,10,80,2080,100000,9/                           BLBJ  36
      DATA LK/180,99,4,2,4,4/                                            BLBJ  37
      END                                                                BLBJ  38
```

================================ APPENDIX B ==================================

CARD FORMAT FOR DATA INPUT

==

FIGURE 1. CONTROL CARD (INPUT)

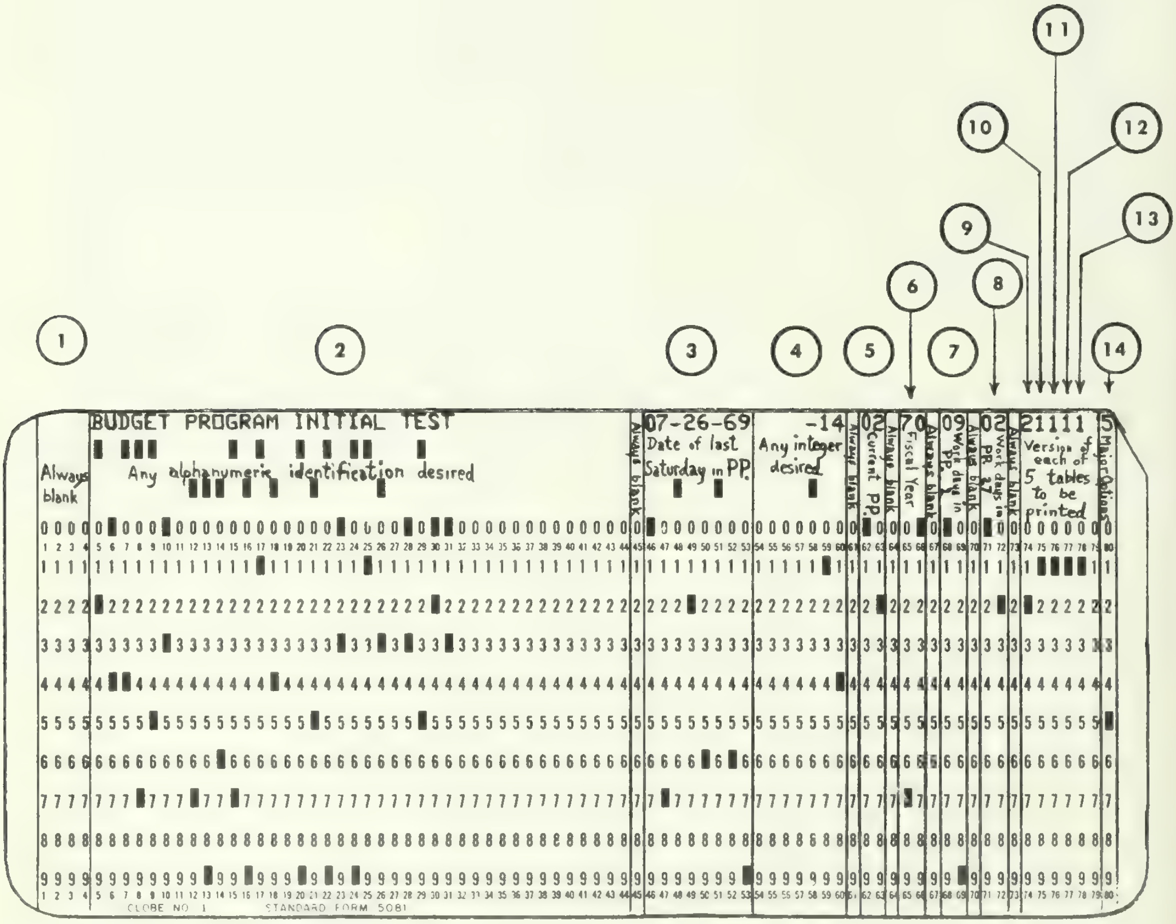

FIGURE 1. (CONTINUED)

CONTROL CARD FORMAT.

```
    1 =  JEND  = ALWAYS BLANK (COL. 1-4).

    2 = ALFATH = ALPHANUMERIC IDENTIFICATION (COL. 5-44).

    3 =  JDAT  = DATE CURRENT PAY PERIOD ENDS (COL. 46-53).

    4 =   NT   = ANY INTEGER OR BLANK (COL. 54-60) FOR ANY PARAMETER NEEDED
                 IN OPTIONAL SUBROUTINES.

    5 =  IPP   = SEQUENCE (1-27) OF CURRENT PAY PERIOD IN FY (COL. 62-63).

    6 =  IFY   = FISCAL YEAR (COL. 65-66).

    7 =IPRT(1) = DAYS IN PAY PERIOD 1 (COL. 68-69).

    8 =IPRT(2) = DAYS IN PAY PERIOD 27 (COL. 71-72).

 9-13 =LOP(1-5)= VERSION OF RATES TO BE USED FOR GS-WB SALARY, FEGLI, FEHBA,
                 AND RETIREMENT IN COMPUTATION AND PRINTOUT OF COST-TO-GOV'T
                 TABLES (COL. 74-78).  NO TABLES WILL BE PRINTED IF ANY OF
                 THESE 5 DIGITS ARE ZERO OR GREATER THAN 3.

   14 = LOP(7) = LOPP = PROCESSING OPTIONS 0-9 (COL. 80)
                 0 LIMITS OUTPUT TO SPECIAL COST-TO-GOV'T TABLES.
                 1 LIMITS PROCESSING TO CHECK OF INDEX CARDS.
                 2 LIMITS PROCESSING TO CHECK OF BUDGET CARDS.
                 3 FULL BUDGET SUMMARY, NO PUNCHOUT, NO SUBROUTINE CALLS.
                 4 SAME AS 3 PLUS PUNCHING OF CARRY-FORWARD CARDS.
                 5 SAME AS 4 PLUS PUNCHING OF DETAILED ACCOUNTING CARDS.
                 6 SAME AS 4 (AVAILABLE FOR USER OPTIONS).
                 7, 8, 9 SAME AS 3, 4, 5 PLUS CALL OF OPTIONAL SUBROUTINES.
```

FIGURE 2. INDEX CARD (INPUT)

PRIMARY SUBSCRIPTS OF VECTOR 'IC'

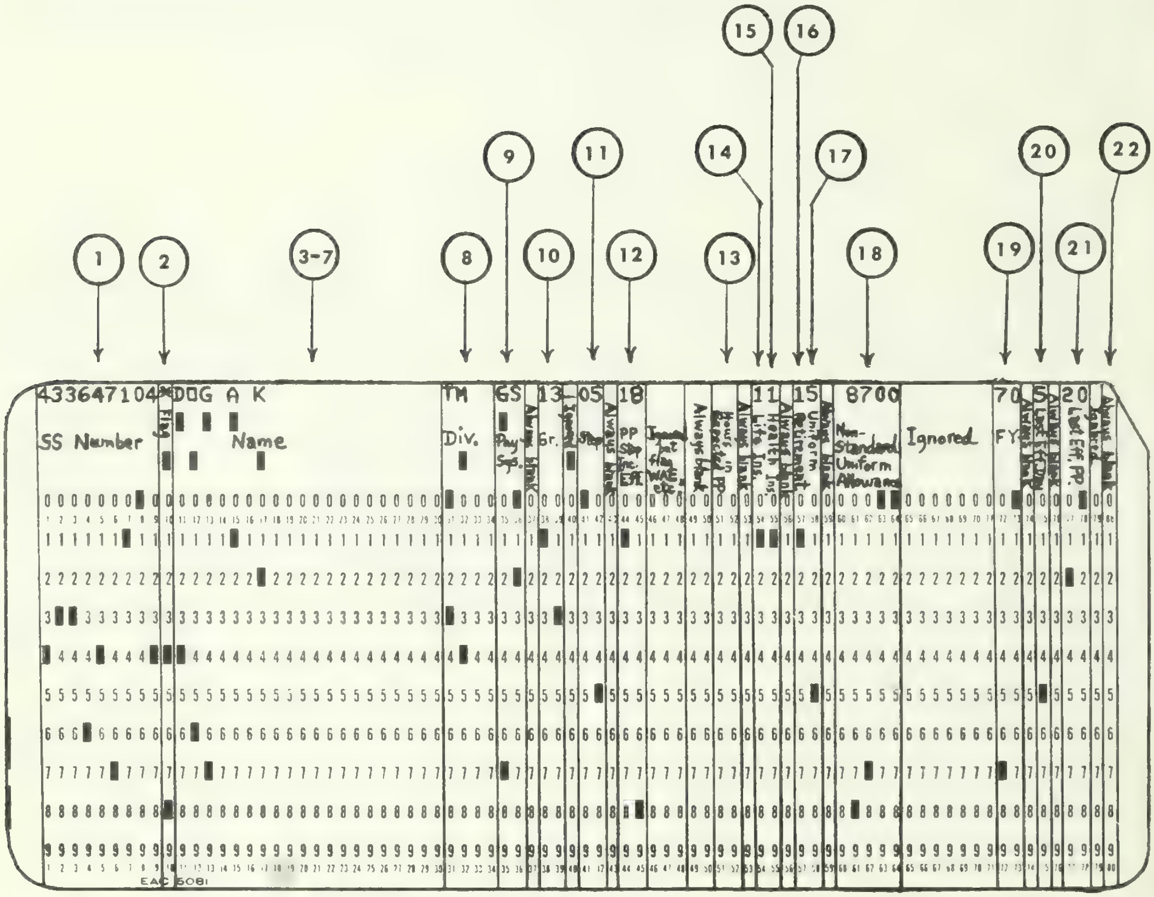

FIGURE 2. (CONTINUED)

INDEX CARD FORMAT (VARIABLES STORED IN 22-CELL VECTOR CALLED 'IC').

IC(1) = SOCIAL SECURITY NUMBER (COL. 1-9).

IC(2) = BLANK EXCEPT * ON FIRST INDEX CARD FOR EACH EMPLOYEE (COL. 10).

IC(3-7)= NAME OF EMPLOYEE (COL. 11-30).

IC(8) = DIVISION IN AGENCY (COL. 31-34, BUT LEAVE COL. 34 BLANK).

IC(9) = 'GS' OR 'WB' DENOTING PAY PLAN (COL. 35-36).

IC(10) = II = GRADE OF EMPLOYEE (COL. 38-39).

IC(11) = JJ = STEP WITHIN GRADE (COL. 41-42).

IC(12) = PAY PERIOD IN CURRENT FY WHEN GS AUTOMATIC STEP-INCREASE BECOMES EFFECTIVE (COL. 44-45).

= IN COL. 47 IS USUALLY A BLANK AND WILL NEVER BE READ BUT MAY CONTAIN SOME CHARACTER (SUCH AS =) TO IDENTIFY TEMPORARY OR PART-TIME PEOPLE.

IC(13) = AGGREGATE HOURS PER PAY PERIOD THAT EMPLOYEE IS EXPECTED TO WORK (COL. 51-52 -- BLANK IMPLIES 80 HOURS).

IC(14) = INDEX OF GOV'T CONTRIBUTION TO FEGLI (COL. 54) -- 0 OR 1.

IC(15) = INDEX OF GOV'T CONTRIBUTION TO FEHBA (COL. 55) -- 0, 1 OR 2.

IC(16) = INDEX OF GOV'T CONTRIBUTION TO RETIREMENT (COL. 57) -- 0,1 OR 2.

IC(17) = INDEX OF GOV'T CONTRIBUTION TO UNIFORM (COL. 58) -- 0-5.

IC(18) = CENTS CONTRIBUTED TO UNIFORM IF INDEX IS 5 (COL. 60-64).

IC(19) = FISCAL YEAR (COL. 72-73).

IC(20) = NUMBER OF DAYS OLDER INDICES ARE EFFECTIVE IN PAY PERIOD DURING OR AT END OF WHICH INDICES CHANGE (COL. 75). BLANK IMPLIES CHANGE AT END OF PAY PERIOD.

IC(21) = LATEST PAY PERIOD IN WHICH INDICES ON CARD ARE EFFECTIVE (COL. 77-78). BLANK IMPLIES EFFECTIVENESS THROUGHOUT REMAINDER OF FISCAL YEAR.

IC(22) = ALWAYS BLANK (COL. 80).

FIGURE 3. BUDGET CARD (INPUT)

ODD SUBSCRIPTS OF VECTOR 'KC'
(CORRESPONDING EVEN SUBSCRIPTS APPLY TO ADJACENT COLUMNS CONTAINING DAYS)

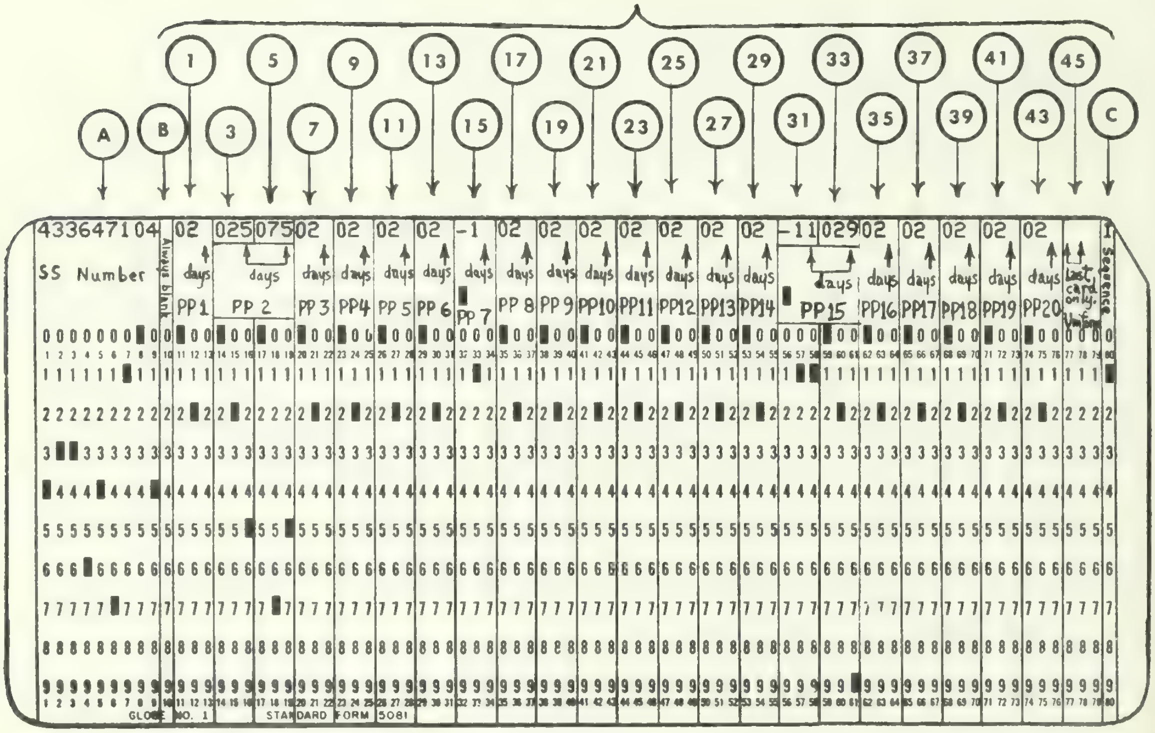

FIGURE 3. (CONTINUED)

BUDGET CARD FORMAT (VARIABLES STORED IN 2-CELL VECTOR CALLED 'LW', IN 'JABC', AND IN 46-CELL VECTOR CALLED 'KC').

A = LW(1) = SOCIAL SECURITY NUMBER (COL. 1-9).

B = JABC = ALWAYS BLANK (COL. 10).

KC = 46-CELL VECTOR (COL. 11-79), WITH ODD CELLS CONTAINING 2-DIGIT APPROPRIATION NUMBER, AND EVEN CELLS CONTAINING 1-DIGIT NUMBER OF DAYS BUDGETED TO THAT APPROPRIATION DURING A PARTICULAR PAY PERIOD. BLANK OR ZERO DAYS IMPLY A FULL PAY PERIOD OF 10 DAYS. KC(45) SHOULD BE BLANK EXCEPT ON LAST BUDGET CARD FOR EACH EMPLOYEE, WHEN COL. 77-78 SHOULD CONTAIN A POSITIVE NONZERO INTEGER DENOTING APPROPRIATION TO WHICH UNIFORM ALLOWANCE IS CHARGEABLE (EVEN THOUGH EMPLOYEE IS NOT ENTITLED TO ANY, SUCH NON-ENTITLEMENT WILL BE TAKEN CARE OF BY A ZERO UNIFORM INDEX ON HIS INDEX CARD). KC(46) SHOULD ALWAYS BE BLANK.

ODD CELLS CONTAINING APPROPRIATION -1 IMPLY LWOP OR POTENTIAL WORK DAYS NOT BUDGETED AS PAID WORK DAYS. EXACTLY 10 DAYS MUST BE BUDGETED FOR EACH OF 27 SUCCESSIVE PAY PERIODS, BUT POTENTIAL WORK DAYS IN PAY PERIODS 1 AND 27 ARE REPLACED BY CORRECT FIGURES GIVEN ON THE CONTROL CARD. 'ISUM' IS THE SUM OF DAYS IN CONSECUTIVE BUDGET PERIODS ACCUMULATED BY THE COMPUTER UNTIL IT AGGREGATES EXACTLY 10 DAYS.

C = LW(2) = DIGIT 1,2,3,4,5,6,7,8 OR 9 SHOWING SEQUENCE OF BUDGET CARD WITHIN SET FOR GIVEN EMPLOYEE (COL. 80).

FIGURE 4. SEPARATOR OR PROGRAM-END CARD (INPUT)

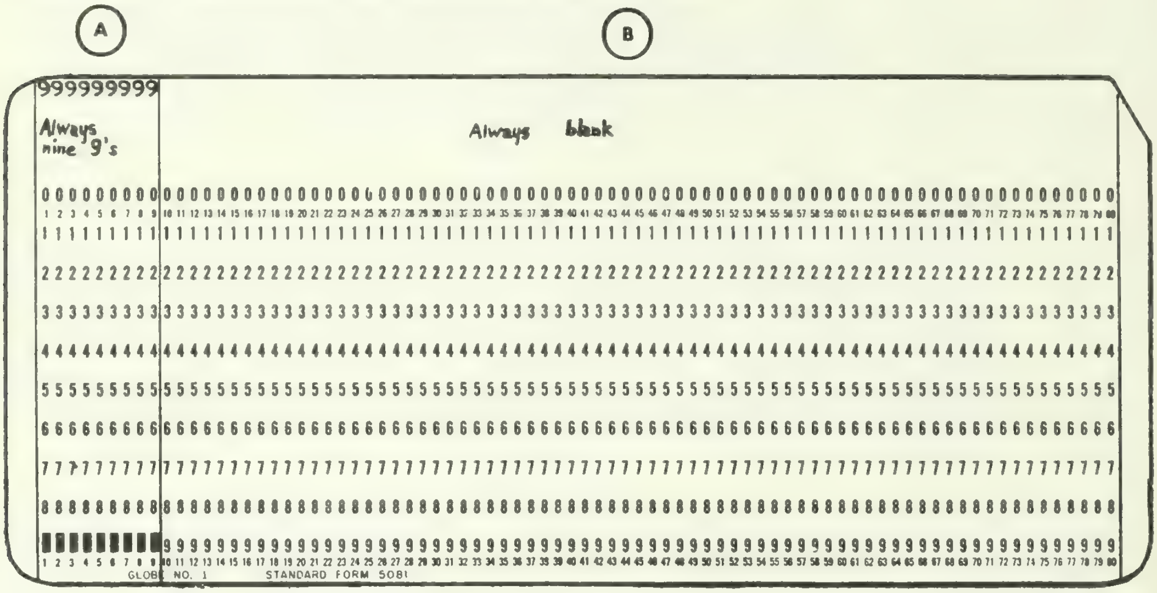

FIGURE 5. BROUGHT- OR CARRY-FORWARD CARD (INPUT OR OUTPUT)

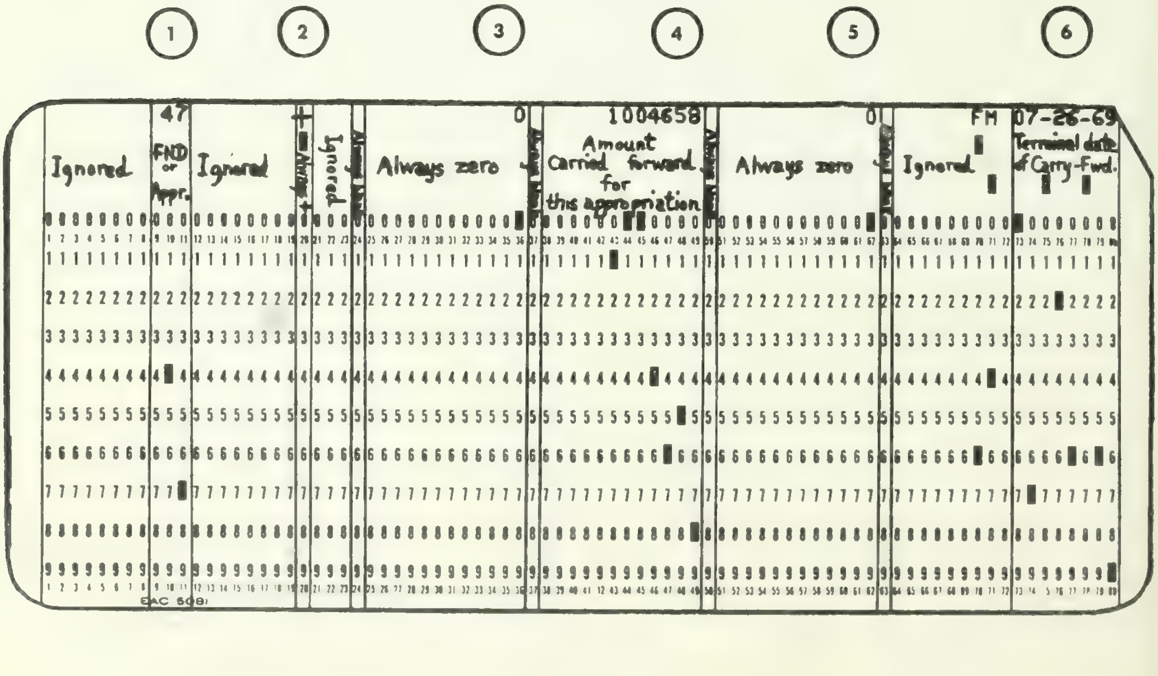

FIGURE 4. (CONTINUED)

SEPARATOR OR PROGRAM-END CARD FORMAT.

A = 999999999 (COL. 1-9). THIS CARD IS USED AS A SEPARATOR FOLLOWING LAST BUDGET CARD AND AGAIN FOLLOWING LAST BROUGHT-FORWARD CARD OF EACH SUCCESSIVE JOB. TWO CONSECUTIVE SEPARATORS MUST APPEAR TOGETHER IF THERE ARE INDEX AND BUDGET CARDS BUT NO BROUGHT-FORWARD CARDS.

NO SEPARATORS SHOULD APPEAR AFTER NAKED CONTROL CARD (ZERO OPTION).

A 999999999 CARD AFTER SECOND SEPARATOR OR AFTER NAKED CONTROL CARD ACTS AS A PROGRAM-END CARD AND RETURNS CONTROL TO SYSTEM. ALTERNATIVELY, JOBS MAY BE STACKED ONE BEHIND THE OTHER AD INFINITUM.

B = ALWAYS BLANK (COL. 10-80).

FIGURE 5. (CONTINUED)

BROUGHT-FORWARD (INPUT) OR CARRY-FORWARD (OUTPUT) CARD FORMAT.

1 = APPROPRIATION CHARGEABLE (COL. 9-11).

2 = ALWAYS PLUS SIGN (COL. 20).

3 = ALWAYS ZERO (COL. 36).

4 = AMOUNT CHARGED TO APPROPRIATION PREVIOUSLY, IF BROUGHT-FORWARD, OR AMOUNT OF CURRENT PLUS PREVIOUS CHARGES, IF CARRY-FORWARD (COL. 38-49). ALL AMOUNTS ARE IN CENTS.

5 = ALWAYS ZERO (COL. 62).

6 = PREVIOUS TERMINAL DATE IF BROUGHT-FORWARD ITEM, OR DATE CURRENT PAY PERIOD ENDS IF CARRY-FORWARD ITEM (COL. 73-80).

FIGURE 6. DETAILED ACCOUNTING CARD (OUTPUT)

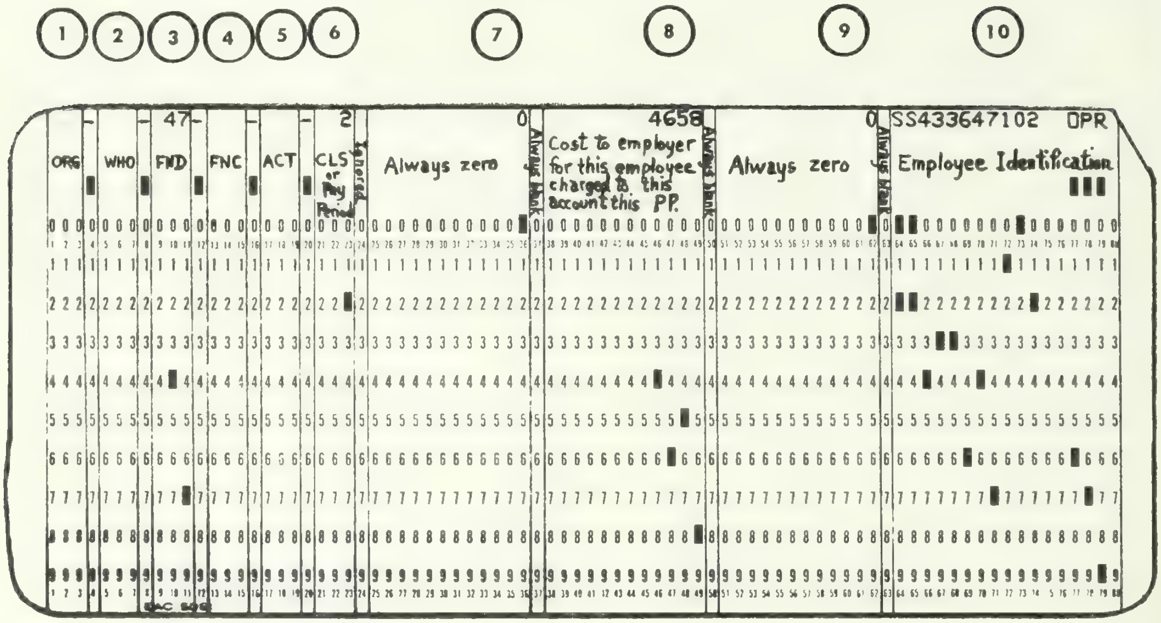

FIGURE 6. (CONTINUED)

DETAILED ACCOUNTING CARD FORMAT.

1,2,4,5 = FOUR 3-CHARACTER FIELDS FOR CODING OF ORGANIZATION, RESPONSIBLE MONEY-MANAGER, FUNCTION, ACCOUNT (COLS. LEFT BLANK ON CARD NOW).

3 = APPROPRIATION CHARGEABLE (COL. 9-11).

6 = ORDINAL NUMBER OF PAY PERIOD, OR ALTERNATIVELY IT COULD BE USED FOR BUDGET OBJECT OR CLASS (COL. 21-23).

7 = ALWAYS ZERO (COL.36).

8 = AMOUNT IN CENTS OF ITEM CURRENTLY BEING CHARGED TO THE APPROPRIATION (COL. 38-49).

9 = ALWAYS ZERO (COL.62).

10 = SOCIAL SECURITY NUMBER AND DIVISION OF EMPLOYEE WHOSE COSTS ARE BEING BROKEN DOWN BY APPROPRIATION (COL. 64-80).

================================= APPENDIX C ==================================

SYSTEM CONTROL CARDS, PROGRAM MODIFICATIONS, AND DECK ARRANGEMENTS SUITABLE FOR RUNNING ON UNIVAC 1108, RCA SPECTRA 70/55, IBM 360, IBM 7094-7044, CDC 6400-6600 WITH LISTING OF SMALL ILLUSTRATORY SET OF INPUT DATA

==

```
CONTROL CARDS, DECK ARRANGEMENT, AND MODIFICATIONS NEEDED TO RUN 'BUDJ'
                   ON UNIVAC 1108 UNDER EXEC VIII
---------------------------------------------------------------------

@RUN     BUDJ01,888888888,GROSENBAUGH, 5,200/100
@ASG,T      B,C,SCRTCH .          ASSIGN MAG TAPE FOR PERS OR REPT.
@ASG,T      C,C,SCRTCH .          ASSIGN MAG TAPE FOR PERS OR REPT.
@USE        4,B .                 EQUATE LOGICAL 4 TO B.
@USE        8,C .                 EQUATE LOGICAL 8 TO C.
@FOR,IS     BUDJ
@FOR,IS     BLBJ
      DATA MRE/ 5/,MPR/ 6/,MPU/ 1/,JW/ 4/,JX/ 8/,MEOF/0/            BLBJ  21
  (ASSIGNMENTS APPROPRIATE TO INSTALLATION I/O CONFIGURATION)
@FOR,IS     PERS
@FOR,IS     REPT
@MAP
@XQT
------------------- PLACE   BCD    INPUT DATA DECK HERE ------------------
@FIN

---------------------------------------------------------------------------
CONTROL CARDS, DECK ARRANGEMENT, AND MODIFICATIONS NEEDED TO RUN 'BUDJ'
              ON RCA SPECTRA 70/55 UNDER TDOS MONITOR
---------------------------------------------------------------------

// JOB BUDJ  GROSENBAUGH  888(7)  82K  5 MIN.
// PARAM LIST=YES,MAP=YES,DEBUG=YES
// FORTRN
      PROGRAM BUDJ
C 'BUDJ' - L.R.GROSENBAUGH'S 7-21-69 PROGRAM FOR SALARY-COST BUDGETING.BUDJ   1
C  STORAGE ARRAYS, PARAMETERS, AND CONSTANTS NEEDED BY 'BUDJ' 07-21-69.BLBJ   1
      BLOCK DATA                                                    BLBJ   2
      DATA MRE/ 5/,MPR/ 6/,MPU/ 7/,JW/ 4/,JX/ 8/,MEOF/0/            BLBJ  21
  (ASSIGNMENTS APPROPRIATE TO INSTALLATION I/O CONFIGURATION)
      SUBROUTINE PERS                                               PERS   1
      SUBROUTINE REPT                                               REPT   1
// ASSEMBL
DDEVICES START
         PRINT NOGEN
         DATAD DEVICE=TAPE,BUFPOOL=NO,TYPEBUF=NOUSURP,RECFORM=FIXBLK, C
               RECSIZE=80,BLKSIZE=800,DSREF=4,DEVADDR=TAPE4,NUMBUF=2
         DATAD DEVICE=TAPE,BUFPOOL=NO,TYPEBUF=NOUSURP,RECFORM=FIXBLK, C
               RECSIZE=80,BLKSIZE=800,DSREF=8,DEVADDR=TAPE8,NUMBUF=2
         DATAD DSREF=5,DEVICE=MONITOR,DEVADDR=SYSIPT
         DATAD DSREF=6,DEVICE=MONITOR,DEVADDR=SYSLST,CONTROL=SYSTEM
         DATAD DSREF=7,DEVICE=MONITOR,DEVADDR=SYSOPT
         DATAD
         END
// LNKEDT
 PROG BUDJ
// EXEC BUDJ
------------------- PLACE  EBCDIC  INPUT DATA DECK HERE ------------------
```

```
CONTROL CARDS, DECK ARRANGEMENT, AND MODIFICATIONS NEEDED TO RUN 'BUDJ'
                       ON IBM 360 UNDER O.S. 360
------------------------------------------------------------------------

//JXXXXBJ  JOB  (XXXX,50,50,1000),GROSENBAUGH,MSGLEVEL=1
//CLG  EXEC  FORTGCLG,PARM.FORT='DECK,LOAD,SOURCE,EBCDIC,NAME=BUDJ'
//FORT.SYSIN  DD  *
C 'BUDJ' - L.R.GROSENBAUGH'S 7-21-69 PROGRAM FOR SALARY-COST BUDGETING.BUDJ   1
C  STORAGE ARRAYS, PARAMETERS, AND CONSTANTS NEEDED BY 'BUDJ' 07-21-69.BLBJ   1
      BLOCK DATA                                                        BLBJ   2
      DATA MRE/ 5/,MPR/ 6/,MPU/ 7/,JW/ 4/,JX/ 8/,MEOF/0/                BLBJ  21
  (ASSIGNMENTS APPROPRIATE TO INSTALLATION I/O CONFIGURATION)
      SUBROUTINE PERS                                                   PERS   1
      SUBROUTINE REPT                                                   REPT   1
/*
//GO.FT04F001  DD  DSNAME=&TAPE4,UNIT=SYSSQ,SPACE=(CYL,(20,20)),       X1
               DISP=(NEW,DELETE)                                        2
//GO.FT08F001  DD  DSNAME=&TAPE8,UNIT=SYSSQ,SPACE=(CYL,(20,20)),       X1
               DISP=(NEW,DELETE)                                        2
//GO.SYSIN  DD  *
--------------------  PLACE  EBCDIC  INPUT DATA DECK HERE  -------------------
/*
//

--------------------------------------------------------------------------------
CONTROL CARDS, DECK ARRANGEMENT, AND MODIFICATIONS NEEDED TO RUN 'BUDJ'
                       ON IBM 7094 UNDER IBSYS
------------------------------------------------------------------------

$JOB   XX      5,100,10000          GROSENBAUGH-21.
$IBJOB BUDJCP  MAP
$IBFTC BUDJ    DECK                                                     BUDJ   0
$IBFTC BLBJ    DECK                                                     BLBJ   0
      DATA MRE/ 5/,MPR/ 6/,MPU/ 7/,JW/ 4/,JX/ 8/,MEOF/0/                BLBJ  21
  (ASSIGNMENTS APPROPRIATE TO INSTALLATION I/O CONFIGURATION)
$IBFTC PERS    DECK                                                     PERS   0
$IBFTC REPT    DECK                                                     REPT   0
$ENTRY         BUDJ
$DATA
--------------------  PLACE   BCD    INPUT DATA DECK HERE  -------------------
$EOF

     (SETUP FOR IBM 7044 DIFFERS ONLY IN JOB CARD, DELETION OF $DATA CARD,
      EXPANSION OF EQUIVALENCE DECLARATIONS FOR JJJ AND KKK SO THAT NUMBER
           OF DATA-STATEMENT CONTINUATION-CARDS DOES NOT EXCEED 9,
                 AND REPLACEMENT OF $EOF CARD BY $IBSYS CARD)
```

```
CONTROL CARDS, DECK ARRANGEMENT, AND MODIFICATIONS NEEDED TO RUN 'BUDJ'
                      ON CDC 6400-6600 UNDER SCOPE 3.0
---------------------------------------------------------------------------

JXXXXBJ,7,400,55000.XXXX,GROSENBAUGH-13.BUDJ
RUN(P,55000,,,,,12000,1,1)
LGO.
CDC RECORD SEPARATOR CARD, WITH 7,8,9 PUNCHED IN COLUMN ONE.
      OPROGRAM BUDJ(INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,
      1TAPE7=PUNCH,TAPE4,TAPE8)
C 'BUDJ' - L.R.GROSENBAUGH'S 7-21-69 PROGRAM FOR SALARY-COST BUDGETING.BUDJ    1
C  STORAGE ARRAYS, PARAMETERS, AND CONSTANTS NEEDED BY 'BUDJ' 07-21-69.BLBJ    1
      BLOCK DATA                                                      BLBJ    2
      DATA MRE/ 5/,MPR/ 6/,MPU/ 7/,JW/ 4/,JX/ 8/,MEOF/0/              BLBJ   21
  (ASSIGNMENTS APPROPRIATE TO PROGRAM CARD I/O EQUIVALENCES)
      SUBROUTINE PERS                                                 PERS    1
      SUBROUTINE REPT                                                 REPT    1
CDC RECORD SEPARATOR CARD, WITH 7,8,9 PUNCHED IN COLUMN ONE.
-------------------- PLACE   BCD    INPUT DATA DECK HERE -------------------
CDC END-OF-FILE CARD, WITH 6,7,8,9 PUNCHED IN COLUMN ONE.
```

ILLUSTRATIVE EXAMPLE OF VALID DATA CARD INPUT TO 'BUDJ'

```
    BUDGET PROGRAM INITIAL TEST              07-26-69    -14 02 70 09 02 21111 5
433647101*ABLE J M            OPR WB  08-03          02 20             70
433647101 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02    1
433647101 02 02 02 02 02                                                    02 2
433647102*BAKER K R           OPR WB  06-04   =   48 11 10             70
433647102 47 -17473-14476-14476-14476-14476-14476-14476-14476-14476-14476-14   1
433647102 476-14476-14476-14476-14476-14476-14476-14476-14476-14476-14476-14   2
433647102 476-14476-14476-14476-1                                           47 3
433647103*CHARLIE F M         OPR GS  12-04          11 11             70
433647103 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02    1
433647103 02 02 02 02 02                                                    02 2
433647104*DOG A K             TM  GS 13-05  18       11 15  8700       70 5 20
433647104 DOG A K             TM  GS 14-01           11 15  8700       70
433647104 02 02507502 02 02 02 -1 02 02 02 02 02 02 02 -1102902 02 02 02 02    1
433647104 02 02 02 02 02 02 02                                              02 2
999999999
        002        +               0     10000000            0       FM 07-12-69
        007        +               0       100000            0       FM 07-12-69
        047        +               0      1000000            0       FM 07-12-69
999999999
999999999
```

```
================================ APPENDIX D ===================================
          OUTPUT FROM INPUT DATA LISTED IN PREVIOUS APPENDIX
===============================================================================
```

FIGURE 7. EXCERPT FROM 'GS' COST-TO-GOV'T TABLE (OPTIONAL OUTPUT)

```
                     (GS) (GS) COST-TO-GOVT 07-26-69                     PAGE   4
======================================/========================================
GR-ST SAL80HR LIFCOST HIHCOST CSRCOST /  GR-ST SAL80HR LIFCOST HIHCOST CSRCOST
                      LOHCOST SSRCOST /                        LOHCOST SSRCOST
======================================/========================================
                                      /
11- 3   46080     192     410    2995 /  12-10   66960     275     410    4352
                          168    1440 /                            168    1440
                                      /
11- 4   47520     206     410    3089 /  13- 1   60800     247     410    3952
                          168    1440 /                            168    1440
                                      /
11- 5   48960     206     410    3182 /  13- 2   62880     261     410    4087
                          168    1440 /                            168    1440
                                      /
11- 6   50400     220     410    3276 /  13- 3   64880     261     410    4217
                          168    1440 /                            168    1440
                                      /
11- 7   51840     220     410    3370 /  13- 4   66880     275     410    4347
                          168    1440 /                            168    1440
                                      /
11- 8   53280     220     410    3463 /  13- 5   68960     275     410    4482
                          168    1440 /                            168    1440
                                      /
11- 9   54720     234     410    3557 /  13- 6   70960     289     410    4612
                          168    1440 /                            168    1440
                                      /
11-10   56160     234     410    3650 /  13- 7   72960     289     410    4742
                          168    1440 /                            168    1440
                                      /
12- 1   51520     220     410    3349 /  13- 8   75040     302     410    4878
                          168    1440 /                            168    1440
                                      /
12- 2   53200     220     410    3458 /  13- 9   77040     316     410    5008
                          168    1440 /                            168    1440
                                      /
12- 3   54960     234     410    3572 /  13-10   79040     316     410    5138
                          168    1440 /                            168    1440
                                      /
12- 4   56640     234     410    3682 /  14- 1   71280     289     410    4633
                          168    1440 /                            168    1440
                                      /
12- 5   58320     247     410    3791 /  14- 2   73680     302     410    4789
                          168    1440 /                            168    1440
                                      /
12- 6   60080     247     410    3905 /  14- 3   76000     302     410    4940
                          168    1440 /                            168    1440
                                      /
12- 7   61760     261     410    4014 /  14- 4   78400     316     410    5096
                          168    1440 /                            168    1440
                                      /
12- 8   63520     261     410    4129 /  14- 5   80800     330     410    5252
                          168    1440 /                            168    1440
                                      /
12- 9   65200     261     410    4238 /  14- 6   83120     330     410    5403
                          168    1440 /                            168    1440
```

FIGURE 8. EXCERPT FROM 'WB' COST-TO-GOV'T TABLE (OPTIONAL OUTPUT)

```
                       (WB) (WB) COST-TO-GOVT 07-26-69                          PAGE   8
===================================================/==================================================
GR-ST  SAL8OHR  LIFCOST  HIHCOST  CSRCOST  /  GR-ST  SAL8OHR  LIFCOST  HIHCOST  CSRCOST
                         LOHCOST  SSRCOST  /                           LOHCOST  SSRCOST
===================================================/==================================================
                                           /
 4- 8   29680     137      410     1929    /   6- 7   31360     151      410     2038
                           168     1425    /                             168     1440
                                           /
 4- 9   31200     151      410     2028    /   6- 8   33040     151      410     2148
                           168     1440    /                             168     1440
                                           /
 5- 1   19680     137      410     1279    /   6- 9   34720     165      410     2257
                           168      945    /                             168     1440
                                           /
 5- 2   20720     137      410     1347    /   7- 1   22880     137      410     1487
                           168      995    /                             168     1098
                                           /
 5- 3   21760     137      410     1414    /   7- 2   24080     137      410     1565
                           168     1044    /                             168     1156
                                           /
 5- 4   21680     137      410     1409    /   7- 3   25280     137      410     1643
                           168     1041    /                             168     1213
                                           /
 5- 5   22800     137      410     1482    /   7- 4   25120     137      410     1633
                           168     1094    /                             168     1206
                                           /
 5- 6   23920     137      410     1555    /   7- 5   26480     137      410     1721
                           168     1148    /                             168     1271
                                           /
 5- 7   29760     137      410     1934    /   7- 6   27840     137      410     1810
                           168     1428    /                             168     1336
                                           /
 5- 8   31360     151      410     2038    /   7- 7   32960     151      410     2142
                           168     1440    /                             168     1440
                                           /
 5- 9   32960     151      410     2142    /   7- 8   34720     165      410     2257
                           168     1440    /                             168     1440
                                           /
 6- 1   21280     137      410     1383    /   7- 9   36480     165      410     2371
                           168     1021    /                             168     1440
                                           /
 6- 2   22400     137      410     1456    /   8- 1   24480     137      410     1591
                           168     1075    /                             168     1175
                                           /
 6- 3   23520     137      410     1529    /   8- 2   25760     137      410     1674
                           168     1129    /                             168     1236
                                           /
 6- 4   23440     137      410     1524    /   8- 3   27040     137      410     1758
                           168     1125    /                             168     1298
                                           /
 6- 5   24640     137      410     1602    /   8- 4   26880     137      410     1747
                           168     1183    /                             168     1290
                                           /
 6- 6   25840     137      410     1680    /   8- 5   28320     137      410     1841
                           168     1240    /                             168     1359
```

FIGURE 9. EMPLOYEE COST-TO-GOV'T BY APPROP. (PAST, CURRENT, FUTURE, TOTAL)
(STANDARD OUTPUT FOR ANY OPTION GREATER THAN 2 IF INPUT IS ERROR-FREE)
(FOR OPTIONAL CARD OUTPUT, SEE FIGURES 5 AND 6)

```
                   BUDGET PROGRAM INITIAL TEST                         PAGE   1
===============================================================================
SS NUMBER NAME                 DIV DAS APPROPRIATION FY70 PP  2 ENDING 07-26-69
===============================================================================

433647101 ABLE J M             OPR  10   2-                               28506
433647102 BAKER K R            OPR   3  47-                                4658
433647103 CHARLIE F M          OPR  10   2-                               60966
```

```
                   BUDGET PROGRAM INITIAL TEST                         PAGE   2
===============================================================================
SS NUMBER NAME                 DIV DAS APPROPRIATION FY70 PP  2 ENDING 07-26-69
===============================================================================

433647104 DOG A K              TM    5   2-                               37064
                                     5   7-                               37064
```

```
          BUDGET PROGRAM INITIAL TEST                                  PAGE   3
===============================================================================
              SAL.COSTS   PAY PD  2   PROJECTED   TOTAL EST.
              PREVIOUSLY  COSTS THRO  SAL.COSTS   SAL.COSTS
   APPROP.    INCURRED    07-26-69    TO 06-30-70   FY 70
============================================================
      2        10000000      126536     3915465    14042001
      7          100000       37064           0      137064
     47         1000000        4658      223560     1228218
------------------------------------------------------------
   ALL APPR    11100000      168258     4139025    15407283
```

```
999BUDGET PROGRAM INITIAL TEST              07-26-69    -14  2 70  9  2 2111105

             1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
             1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
             1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
             1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
             1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
             1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

      0               4           4     4551834      244553
      0         5058110       33530        1433         578
      0           21553       37700
```

(FOR EXPLANATION OF TERMINATING OUTPUT ABOVE, SEE PAGES 8-9)

================================ APPENDIX E ====================================

ERROR DIAGNOSTIC CODE, LISTING OF SEVERAL ERRONEOUS INPUTS, AND PRINTOUT OF RESULTANT ERROR MESSAGES

==

```
                         'BUDJ 07-21-69' ERROR DIAGNOSTIC CODE

 CONTROL CARD ERRORS
      IF (IPP .LT. 1   .OR. IPP .GT. 27)                             ERROR   -1
      IF (IPRT(1)+IPRT(2) .LT. 10 .OR. .GT. 12)                      ERROR    0

 INDEX CARDS ERRORS
      IF (IC(22,J) .NE. 0)                                           ERROR  151
      IF (IC(19,J) .NE. IFY)                                         ERROR  152
      IF (IC(21,J) .LT. 0 .OR. IC(12,J) .LT. 0)                      ERROR  153
      IF (IC(21,J) .GT. 26 .OR. IC(12,J) .GT. 26)                    ERROR  154
      IF (IC(21,J) .EQ. 0 .AND. IC(20,J) .NE. 0)                     ERROR  155
      IF (IC(21,J) .EQ. 1 .AND. IC(20,J) .NE. 0)                     ERROR  155
      IF (IC(21,K) .NE. 0 .AND. IC(1,J) .NE. IC(1,K))                ERROR  156
      IF (IC(2,J) .NE. * .AND. IC(1,J) .NE. IC(1,K))                 ERROR  157
      IF (IC(21,K) .EQ. 0 .AND. IC(1,J) .EQ. IC(1,K))                ERROR  158
      IF (IC(21,J) .LT. IC(21,K) .AND. IC(21,J) .NE. 0)              ERROR  159
      IF (II .LE. 0 .OR. JJ .LE. 0)                                  ERROR  160
      IF (IC(18,J) .NE. 0 .AND. IC(17,J) .LT. 5)                     ERROR  161
      IF (IC(14,J) .GT. 1)                                           ERROR  162
      IF (IC(15,J) .GT. 2)                                           ERROR  163
      IF (IC(16,J) .GT. 2)                                           ERROR  164
      IF (IC(1,J) .LE. 0)                                            ERROR  165
      IF (IC(12,J) .GT. 0 .AND. JJ .GT. 9)                           ERROR  166
      IF ((II .GT. 11 .OR. JJ .GT. 9) .AND. IC(9,J) .EQ. WB)         ERROR  167
      IF (IC(12,J) .NE. 0 .AND. IC(9,J) .EQ. WB)                     ERROR  168
      IF (IC(9,J) .NE. GS .AND. IC(9,J) .NE. WB)                     ERROR  169
      IF (II .GT. 18 .OR. JJ .GT. 10)                                ERROR  170

 BUDGET CARDS ERRORS (ASSUMING INDEX CARDS ARE FLAWLESS)
      IF (LW(1,J) .EQ. 999999999)                                    ERROR  251
      IF (LW(2,J) .EQ. 0)                                            ERROR  252
      IF (JABC .NE. BLANK)                                           ERROR  253
      IF (LW(2,J) .NE. 1 .AND. LW(2,J) .NE. LW(2,K)+1)               ERROR  254
      IF (LW(1,J) .NE. LW(1,K) .AND. LW(2,J) .NE. 1)                 ERROR  254
      IF (ISUM .NE. 10)                                              ERROR  255
      IF (KC(45) .NE. 0 ON CARD NOT CONTAINING 27TH PAY-PD.)         ERROR  256
      IF (APPROPRIATION .NE. 0 AFTER 270-DAY ACCUMULATION)           ERROR  257
      IF (KC(45) .LE. 0 ON CARD CONTAINING 27TH PAY-PD.)             ERROR  258
      IF (APPROPRIATION .EQ. 0 BEFORE 270-DAY ACCUMULATION)          ERROR  259
      IF (LW(1,J) .NE. IC(1,J))                                      ERROR  260

      SUBSCRIPT 'J' IMPLIES CURRENT VECTOR OF IC OR LW (MOST RECENTLY READ).
      SUBSCRIPT 'K' IMPLIES VECTOR OF IC OR LW PREVIOUS TO CURRENT VECTOR.
      THUS, IC AND LW CAN BE REGARDED AS PUSH-DOWN STACKS LOSING ALL BELOW 'K'.
      DEFINITIONS OF IC, LW, IPP, IPRT, IFY, II, JJ, JABC, ISUM, AND KC(45)
                       MAY BE FOUND IN APPENDIX B (INPUT).
```

CONTROL CARD ERRORS ARE DENOTED BY -1 AND 0, AND ARE ACCUMULATED IN THE SAME AGGREGATE AS INDEX CARD ERRORS.

ERROR MESSAGES PRINT AGGREGATE NUMBER OF SIMILAR ERRORS, AS WELL AS 'N' (THE NUMBER OF EMPLOYEES WHOSE INDEX CARDS HAVE PREVIOUSLY BEEN CHECKED OUT O.K.) AND 'M' (THE NUMBER OF EMPLOYEES WHOSE BUDGET CARDS HAVE PREVIOUSLY BEEN CHECKED OUT O.K.). REMEMBER THAT AN INDEX CARD ERROR STOPS ALL FURTHER CHECK OF INDEX OR BUDGET DATA FOR THAT PARTICULAR EMPLOYEE. ALSO REMEMBER THAT ERRORS 157, 158, AND 165 (WITH BLANK OR ZERO SOCIAL SECURITY NUMBER) CANNOT BE DETECTED UNLESS THE PRECEDING EMPLOYEE HAS HAD FAULTLESS CARDS AND THE OPTION PUNCHED IN COLUMN 80 OF THE CONTROL CARD IS GREATER THAN 2. FINALLY, REMEMBER THAT ANY EMPLOYEE WHOSE INITIAL INDEX CARD LACKS AN ASTERISK WILL BE SKIPPED COMPLETELY UNDER OPTION 1 OR IMMEDIATELY FOLLOWING ANY OTHER ERROR.

CONTROL CARD ERROR MESSAGES (NUMBERS -1, 0) GIVE ONLY CUMULATIVE NUMBER OF SIMILAR ERRORS.

INDEX CARD ERROR MESSAGES (NUMBERS 151-170) GIVE NOT ONLY THE CUMULATIVE NUMBER OF CONTROL AND INDEX CARD ERRORS, BUT ALSO 'N' AND 'M' DEFINED ABOVE. ADDITIONAL PRINTOUT CONSISTS OF CURRENT VALUES FOR THE FOLLOWING CELLS OF 'IC' -- (1), (22), (2), (20), (21), WITH IMMEDIATELY PREVIOUS VALUES PRINTED DIRECTLY BELOW EACH. PREVIOUS VALUES OF 'IC' WILL HAVE BEEN INITIALIZED IF THE INDEX CARDS OF THE PRECEDING EMPLOYEE CONTAINED AN ERROR.

BUDGET CARD ERROR MESSAGES (NUMBERS 251-260) GIVE NOT ONLY THE CUMULATIVE NUMBER OF BUDGET CARD ERRORS, BUT ALSO 'N' AND 'M'. ADDITIONAL PRINTOUT CONSISTS OF CURRENT VALUES OF LW(1), LW(2), JABC, KC(45), KC(46), WITH PREVIOUS VALUES OF LW(1) AND LW(2) DIRECTLY BENEATH. AN ERROR IMMEDIATELY PRECEDING CAUSES INITIALIZATION OF PREVIOUS 'LW'.

MOST SEQUENCING ERRORS CAUSED BY DISARRAY CAN BE DIAGNOSED FROM THE ERROR MESSAGE ITSELF, BUT SCAN OF INPUT DATA IDENTIFIED BY ERROR MESSAGE WILL BE NECESSARY IN OTHER CASES.

INPUT DATA SO BADLY PUNCHED THAT IT DOES NOT CONFORM TO SPECIFIED FORMAT WILL NOT BE READABLE BY PROGRAM, BUT THE MONITOR SYSTEM SHOULD FLAG IT ADEQUATELY ENOUGH FOR USER TO LOCATE THE OFFENDING CARD. ONLY THROUGH USE OF NONSTANDARD-FORTRAN (I.E., NON-USASI-FORTRAN) FEATURES SUCH AS 'REREAD' OR 'ERR= ' COULD FORMAT VIOLATIONS BE PROGRAM-DIAGNOSED, AND THIS WAS DEEMED UNDESIRABLE BECAUSE IT WOULD INTRODUCE A VEXING INCOMPATIBILITY INTO A PROGRAM CONFORMING COMPLETELY TO USASI FORTRAN IN ALL OTHER RESPECTS.

ITEMS GIVING A CLUE TO THE PARTICULAR ERROR HAVE BEEN ENCIRCLED ON BOTH INPUT LISTING AND ERROR MESSAGE, WHERE PRINTED, TO HELP USER BETTER UNDERSTAND ERROR AVOIDANCE AND DETECTION.

EXAMPLE OF ERRONEOUS INPUTS FOLLOWED BY ERROR MESSAGES

```
    BUDGET PROGRAM CONTROL CARD ERRORS        07-12-69     -2 00 70 07 02        3
011111111*ZEROMINUSONE        OPR GS 12-04           11 11             70
011111111 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
011111111 91 91 91 91 91                                                    91 2
999999999
999999999


    BUDGET PROGRAM INDEX AND BUDGET ERRORS   07-12-69     -3 01 70 09 02        3
433647101*ABLE                OPR GS 10-10           11 11             70       9
433647101 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
433647101 91 91 91 91 91                                                    91 2
433647102*BAKER               OPR GS 10-10           11 11             69
433647102 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
433647102 91 91 91 91 91                                                    91 2
433647103*CHARLIE             OPR GS 10-10           11 11             70   -5
433647103 CHARLIE             OPR GS 11-01         1 1 1 1             70
433647103 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
433647103 91 91 91 91 91                                                    91 2
433647104*DOG                 OPR GS 10-10           11 11             70   28
433647104 DOG                 OPR GS 11-01           11 11             70
433647104 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
433647104 91 91 91 91 91                                                    91 2
433647105*EASY                OPR GS 10-10           11 11             70 5 01
433647105 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
433647105 91 91 91 91 91                                                    91 2
433647106*FOX                 OPR GS 10-10           11 11             70   10
433646666 FOX                 OPR GS 10-10           21 11             70
433647106 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
433647106 91 91 91 91 91                                                    91 2
433647107*GEORGE              OPR GS 10-10           11 11             70   10
433647107 GEORGE              OPR GS 11-01         1 1 1 1             70
433647107 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
433647107 91 91 91 91 91                                                    91 2
433647108 HOW                 OPR GS 10-10           11 11             70
433647108 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
433647108 91 91 91 91 91                                                    91 2
433647109*ITEM                OPR GS 10-10           11 11             70
433647109 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
433647109 91 91 91 91 91                                                    91 2
433647109*JIG                 OPR GS 10-10           11 11             70
433647109 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
433647109 91 91 91 91 91                                                    91 2
433647111*KING                OPR GS 10-09           11 11             70   20
433647111 KING                OPR GS 10-10           11 11             70   10
433647111 KING                OPR GS 11-01           11 11             70
433647111 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91        1
433647111 91 91 91 91 91                                                    91 2
```

```
433647112*LOVE                OPR GS 10-10           11 11             70
433647112 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647112 91 91 91 91 91                                                    91 2
433647113*MIKE                OPR GS 10-10           11 11 10000       70
433647113 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647113 91 91 91 91 91                                                    91 2
433647114*NAN                 OPR GS 10-10           21 11             70
433647114 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647114 91 91 91 91 91                                                    91 2
433647115*OBOE                OPR GS 10-10           13 11             70
433647115 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647115 91 91 91 91 91                                                    91 2
433647116*PETER               OPR GS 10-10           11 31             70
433647116 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647116 91 91 91 91 91                                                    91 2
-00000001*QUEEN               OPR GS 10-10           11 11             70
-00000001 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
-00000001 91 91 91 91 91                                                    91 2
433647117*ROGER               OPR GS 10-10 23        11 11             70
433647117 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647117 91 91 91 91 91                                                    91 2
433647118*SUGAR               OPR WB 12-10           11 11             70
433647118 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647118 91 91 91 91 91                                                    91 2
433647119*TARE                OPR WB 11-01 23        11 11             70
433647119 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647119 91 91 91 91 91                                                    91 2
433647120*UNCLE               OPR AB 10-10           11 11             70
433647120 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647120 91 91 91 91 91                                                    91 2
433647121*VICTOR              OPR GS 19-10           11 11             70
433647121 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647121 91 91 91 91 91                                                    91 2
433647131*ABLEABLE            TM  GS 12-04           11 11             70
999999999
433647131 91 91 91 91 91                                                    91 2
433647132*BAKERBAKER          TM  GS 12-04           11 11             70
433647132 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91
433647132 91 91 91 91 91                                                    91 2
433647133*CHARLIECHARLIE      TM  GS 12-04           11 11             70
433647133*91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647133 91 91 91 91 91                                                    91 2
433647134*DOGDOG              TM  GS 12-04           11 11             70
433647134 915915915915915915915915915915915915915915915915915915915915915915   2
433647134 91 915915915915915915915915915915915915915915915915915915915915915   1
433647134 91591 91 91 91 91                                                 91 3
433647135*EASYEASY            TM  GS 12-04           11 11             70
433647135 91 91891891 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647135 91 91 91 91 91 91                                                 91 2
433647136*FOXFOX              TM  GS 12-04           11 11             70
433647136 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 77 1
433647136 91 91 91 91 91                                                    77 2
```

```
PAGE   40                         BUDJ 7-21-69

433647137*GEORGEGEORGE        TM  GS 12-04           11 11             70
433647137 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647137 91 91 91 91 91 28                                                 91 2
433647138*HOWHOW              TM  GS 12-04           11 11             70
433647138 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647138 91 91 91 91 91                                                       2
433647139*ITEMITEM            TM  GS 12-04           11 11             70
433647139 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647139 91 91                                                             91 2
433647140*JIGJIG              TM  GS 12-04           11 11             70
433647141 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91 91    1
433647141 91 91 91 91 91                                                    91 2
999999999
999999999
999999999
```

```
  BUDGET PROGRAM CONTROL CARD ERRORS        07-12-69      -2  0 70  7  2          3
ERROR  -1,CUM.TOT.SUCH ERRORS=   1, N=

ERROR   0,CUM.TOT.SUCH ERRORS=   2, N=


  BUDGET PROGRAM INDEX AND BUDGET ERRORS    07-12-69      -3  1 70  9  2          3
ERROR 151,CUM.TOT.SUCH ERRORS=   1, N=   0, M=   0   433647101 9 *  0  0
                                                             0 0    0  0

ERROR 152,CUM.TOT.SUCH ERRORS=   2, N=   0, M=   0   433647102 0 *  0  0
                                                             0 0    0  0

ERROR 153,CUM.TOT.SUCH ERRORS=   3, N=   0, M=   0   433647103 0 *  0 -5
                                                             0 0    0  0

ERROR 154,CUM.TOT.SUCH ERRORS=   4, N=   0, M=   0   433647104 0 *  0 28
                                                             0 0    0  0

ERROR 155,CUM.TOT.SUCH ERRORS=   5, N=   0, M=   0   433647105 0 *  5  1
                                                             0 0    0  0

ERROR 156,CUM.TOT.SUCH ERRORS=   6, N=   0, M=   0   433646666 0    0  0
                                                     433647106 0 *  0 10

ERROR 157,CUM.TOT.SUCH ERRORS=   7, N=   1, M=   1   433647108 0    0  0
                                                     433647107 0    0  0

ERROR 158,CUM.TOT.SUCH ERRORS=   8, N=   2, M=   2   433647109 0 *  0  0
                                                     433647109 0 *  0  0

ERROR 159,CUM.TOT.SUCH ERRORS=   9, N=   2, M=   2   433647111 0    0 10
                                                     433647111 0 *  0 20

ERROR 160,CUM.TOT.SUCH ERRORS=  10, N=   2, M=   2   433647112 0 *  0  0
                                                             0 0    0  0

ERROR 161,CUM.TOT.SUCH ERRORS=  11, N=   2, M=   2   433647113 0 *  0  0
                                                             0 0    0  0

ERROR 162,CUM.TOT.SUCH ERRORS=  12, N=   2, M=   2   433647114 0 *  0  0
                                                             0 0    0  0

ERROR 163,CUM.TOT.SUCH ERRORS=  13, N=   2, M=   2   433647115 0 *  0  0
                                                             0 0    0  0

ERROR 164,CUM.TOT.SUCH ERRORS=  14, N=   2, M=   2   433647116 0 *  0  0
                                                             0 0    0  0
```

```
PAGE   42                          BUDJ 7-21-69

  ERROR 165,CUM.TOT.SUCH ERRORS=  15, N=    2, M=    2           -1 0 *   0   0
                                                                  0 0     0   0

  ERROR 166,CUM.TOT.SUCH ERRORS=  16, N=    2, M=    2    433647117 0 *   0   0
                                                                  0 0     0   0

  ERROR 167,CUM.TOT.SUCH ERRORS=  17, N=    2, M=    2    433647118 0 *   0   0
                                                                  0 0     0   0

  ERROR 168,CUM.TOT.SUCH ERRORS=  18, N=    2, M=    2    433647119 0 *   0   0
                                                                  0 0     0   0

  ERROR 169,CUM.TOT.SUCH ERRORS=  19, N=    2, M=    2    433647120 0 *   0   0
                                                                  0 0     0   0

  ERROR 170,CUM.TOT.SUCH ERRORS=  20, N=    2, M=    2    433647121 0 *   0   0
                                                                  0 0     0   0

  ERROR 251,CUM.TOT.SUCH ERRORS=   1, N=    3, M=    2    999999999 0       0   0
                                                                  0 0

  ERROR 252,CUM.TOT.SUCH ERRORS=   2, N=    4, M=    2    433647132 0       0   0
                                                                  0 0

  ERROR 253,CUM.TOT.SUCH ERRORS=   3, N=    5, M=    2    433647133 1 *     0   0
                                                                  0 0

  ERROR 254,CUM.TOT.SUCH ERRORS=   4, N=    6, M=    2    433647134 2       0   0
                                                                  0 0

  ERROR 255,CUM.TOT.SUCH ERRORS=   5, N=    7, M=    2    433647135 1       0   0
                                                                  0 0

  ERROR 256,CUM.TOT.SUCH ERRORS=   6, N=    8, M=    2    433647136 1      77   0
                                                                  0 0

  ERROR 257,CUM.TOT.SUCH ERRORS=   7, N=    9, M=    2    433647137 2      91   0
                                                          433647137 1

  ERROR 258,CUM.TOT.SUCH ERRORS=   8, N=   10, M=    2    433647138 2       0   0
                                                          433647138 1

  ERROR 259,CUM.TOT.SUCH ERRORS=   9, N=   11, M=    2    433647139 2      91   0
                                                          433647139 1

  ERROR 260,CUM.TOT.SUCH ERRORS=  10, N=   12, M=    2    433647141 2      91   0
                                                          433647141 1
 99999999                                                       0   0   0   0   0
          (THE ABOVE LINE IS PRINTED WHEN 'PROGRAM-END' CARD IS READ)
```

NOTICE

Listing and Fortran-4 source deck (BCD or EBCDIC holes) for program 'BUDJ' will be made available by the author to organizations wishing to use the program.

Grosenbaugh, L. R.
1970. BUDJ -- Fortran-4 program for budgeting cost of each employee by funds chargeable and cost schedules applicable during each pay period.

Southeast. Forest Exp. Sta., USDA Forest Serv.
Res. Paper SE-68, 42 pp.

Describes how to use a budgeting program adapted from a high-speed-computer dendrometry program; budget estimates are made by simulating conditions effective in each of 27 biweekly pay periods even though individual employee pay or fringe-benefit changes frequently during a year and though each pay or fringe-benefit schedule changes no more frequently than twice during a year; it will distribute actual and projected employee costs among no more than 99 different cost accounts or appropriations.

CLASSIFICATION (UDC): 651 + U.681.3

RETRIEVAL TERMS: Budgeting; cost-projection; payroll prediction; digital computer program.

Grosenbaugh, L. R.
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RETRIEVAL TERMS: Budgeting; cost-projection; payroll prediction; digital computer program.

USDA Forest Service Research Paper SE-69 November 1970

Estimating Recreation Use at Visitor Information Centers

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Harold K. Cordell
George A. James
Russell F. Griffith

Southeastern Forest Experiment Station - Asheville - North Carolina
U.S. Department of Agriculture - Forest Service

Estimating Recreation Use at Visitor Information Centers

by Harold K. Cordell, George A. James, and Russell F. Griffith

Although considerable research has been devoted to designing and testing sampling models for estimating use on recreation sites and areas, almost no work has been directed toward estimating recreation use within buildings such as visitor information centers and nature museums, along interpretive trails, and at similar developments. Most past effort at such locations has been simply to count number of people. These counts, however, have not provided such needed information as type of activity, length of stay, and visitor origin and do not provide a means for updating estimates in future years. Sound management and planning for recreational developments must include reliable knowledge of the amount and kind of use they receive.

Objectives of this pilot study were to test a sampling technique for estimating the amount and kind of recreation use at visitor information centers, and to determine relationships between use and several related variables that might be used to update estimates in future years.

The sampling technique was tested during 1968 at the Brasstown Bald Visitor Information Center on the Chattahoochee National Forest in northern Georgia. The visitor information center is located atop Brasstown Bald Mountain at Georgia's highest elevation — 4,784 feet — which affords a majestic view of the surrounding countryside. The Brasstown Bald Center is unique in that, although a two-lane paved road runs almost to the top of the mountain, visitors cannot drive to the visitor center building. A 325-car-capacity parking lot is located approximately ½ mile from the building; an elevational difference of several hundred feet (fig. 1). To reach the visitor center building, visitors must either walk the ½-mile interpretive trail, which starts at the parking lot, or use concessionaire bus service at nominal cost. The visitor center building houses an exhibit hall, an observation deck, a fire observation tower (not open to the public), and a small theater for slide programs and educational movies. The visitor center is open to the public from 10 a.m. to 6 p.m. daily from May 1 through October 31.

The sampling problem at Brasstown Bald was more complex than at most other recreational sites. Visitors had several alternatives after entering the parking lot:

(a) Remaining in the general vicinity of the parking lot.

(b) Walking round trip between lot and visitor center building.

(c) Riding the bus round trip between lot and visitor center building.

(d) Riding the bus one way and walking one way.

Cordell and James are Associate Recreation Specialist and Principal Recreation Specialist, respectively, Southeastern Forest Experiment Station, USDA Forest Service, Asheville, N.C. Griffith is Recreation Staff Officer, Cherokee National Forest, USDA Forest Service, Cleveland, Tenn.

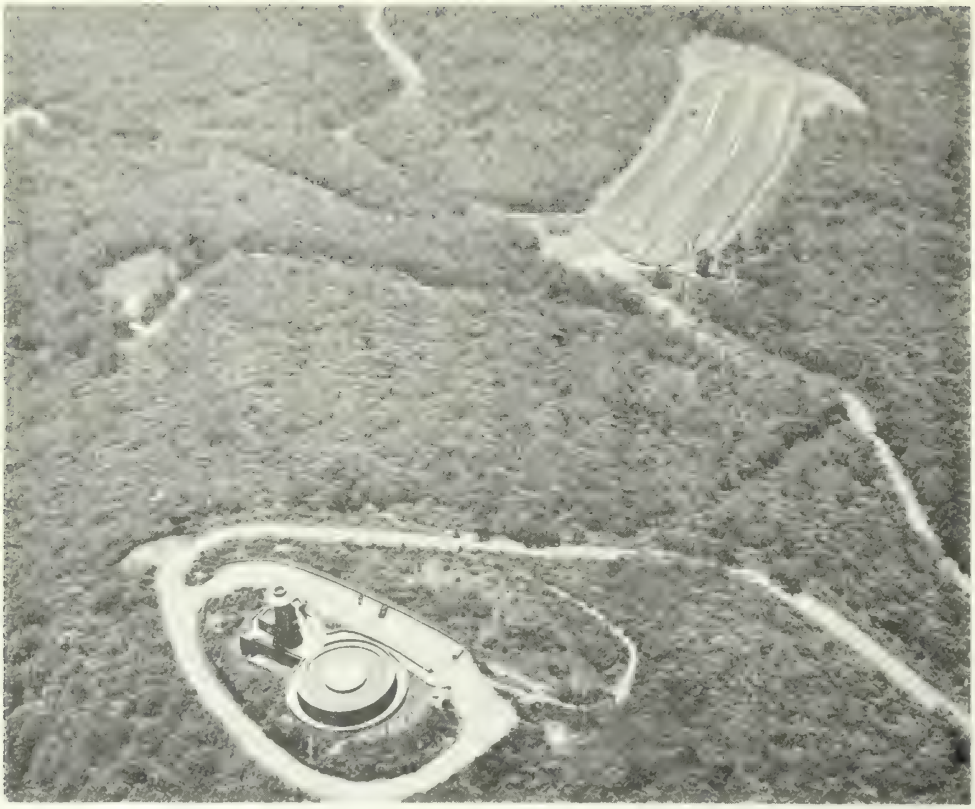

Figure 1. — Brasstown Bald Visitor Information Center showing entrance road, parking lot, and visitor center building.

Techniques and Procedures

The study covered the period May 1 through October 31. The recreation use season of 184 days was sampled on 20 randomly selected days stratified equally between weekdays and weekend/holiday days. Also, a stratified subsample of 12 days was drawn from the 20-day sample to determine if fewer than 20 days might yield acceptable estimates of visits and use. Each sample day was 8 hours in length, 10 a.m. to 6 p.m., to coincide with hours the visitor center building was open to the public. Use during the time the building was closed was not measured.

Sampling procedures were designed to measure use that occurred on each sample day by determining number of visitors and length of stay per visitor. Use statistics were obtained within the following activity zones:

(1) Total use at the site.
(2) Use of bus between parking lot and visitor center building.
(3) Use of trail between parking lot and visitor center building.
(4) Use within the visitor center building, including the exhibit hall, observati deck, and theater.
(5) Use of theater only.
(6) Other use, including time spent wai ing for the bus, picnicking near the parki lot, waiting in vehicles, and undifferentiat activities.

Procedures used to determine visits a use on sample days are described below:

(1) **Total visits and use,** undifferentiat as to kind of activity and place of occurren were estimated by determining number vehicles entering the parking lot, avera number of persons per vehicle, and avera amount of use represented by each vehicle.

Mechanical traffic counters recorded nu ber of vehicles entering the parking lot tween 10 a.m. and 6 p.m. The differen between morning and evening readin equaled the number of vehicles on each sa ple day.

Hours of use represented by each vehi and number of persons per vehicle were termined by observing approximately 75 percent of the vehicles entering the parking lot on eight of the 20 sample days. A Forest Service officer stationed at the entrance to the lot distributed visitor cards to drivers of incoming vehicles during 45 minutes of each hour (fig. 2). Time and date of entry, and number of persons per vehicle, were recorded on each card before it was handed to the driver. Cards were collected as visitors left the site, and time of departure was recorded. Drivers were requested to record time of departure and to deposit the card in a box at the exit if the officer was not present.

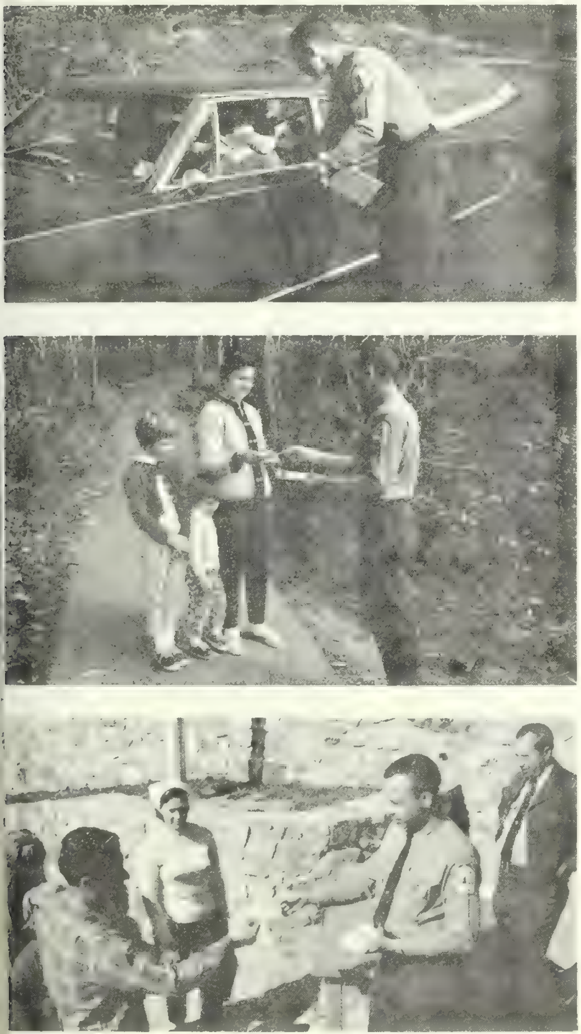

Figure 2.—Colored 3- by 5-inch cards were handed to visitors at the parking lot, trail, and visitor center building. A different colored card was used in each of these activity zones to record date and time of entry and departure, along with other information pertinent to the individual zones.

Average number of persons per vehicle, multiplied by number of vehicles entering the lot, gave an estimate of *total visits* for each sample day. The difference between time of entry and time of departure, multiplied by number of persons in the vehicle, equaled amount of use per vehicle. Average amount of use per vehicle multiplied by total number of vehicles gave an estimate of *total use* undifferentiated by activity.

(2) **Use of bus** was estimated from concessionaire records which included number of tickets sold, number of passengers riding up, and number of passengers riding down. Total number of tickets sold represented the number of different persons riding the bus either one way or both ways per day. The number of passengers riding up added to the number riding down gave number of one-way bus rides. This sum multiplied by average time per ride ($2\frac{1}{2}$ minutes) equaled total bus use per day.

(3) **Number of persons walking the trail** equaled the difference between total visits to the visitor center building and number of persons who rode the bus round trip. Trail use was determined for each of the 20 sample days.

Use of trail was estimated by determining separately the number of persons walking uptrail and the number walking downtrail between the parking lot and visitor center building, and average walking time for the uptrail and downtrail trips. Average walking time for the uptrail and downtrail trips was determined separately from approximately 25 percent of the trail users on eight of the 20 sample days; the same days on which visitor cards were distributed to drivers of incoming vehicles. The officer at the parking lot distributed cards during 15 minutes of every hour to persons beginning the uptrail trip (fig. 2). Date and time of entry onto the trail were recorded on each card. Cards were collected and time of exit recorded by an officer at the visitor center building entrance. Visitors leaving the building on a downtrail trip to the parking lot were also given a card with date and time recorded. They were asked to return the card to the officer at the parking lot who recorded time of exit, or to personally record time of exit and deposit the card in a special box if the officer was not present. The difference between time of entry and time of exit gave estimates of walking time on the trail. Average walking time uptrail was 21.9 minutes and average walking time downtrail was 16.8 minutes.

Average walking time uptrail multiplied by number of persons walking up (total visitors at the information center building minus visitors riding the bus up) represented uptrail use on each sample day. Average walking time downtrail multiplied by number of persons walking down (total visitors at the information center building minus visitors riding the bus down) represented downtrail use. The sum of uptrail and downtrail use gave an estimate of total trail use.

(4) **Visits and use at the visitor center building** were estimated from visitor-card information. A card was given to all persons who entered the building between 10 a.m. and 6 p.m. on sample days (fig. 2). Date and time of entry were recorded on each card. Cards were collected from exiting visitors, and time of departure was recorded with an automatic time-date clock. Cards for children under 6 years old were given to an accompanying adult to avoid loss of cards. The sum of differences between time in and time out represented total use at the visitor center building during the day. Number of cards represented number of visits to the building.

(5) **Use of theater** was determined by counting number of persons attending each slide show and multiplying by length of the slide program (10 minutes).

(6) **All other use** included time spent waiting for the bus, picnicking near the parking lot, waiting in vehicles, and other undifferentiated activity. It was estimated indirectly by subtracting use of bus, trail, and visitor center building from total undifferentiated use for the entire site.

After vehicle license tags were observed, state-of-origin information was recorded on each visitor card distributed at the parking lot. This information was obtained from approximately 75 percent of the entering vehicles on 8 sample days. Visitor-origin information was also obtained from a self-registration guest book, located in the visitor center building exhibit hall.

In addition to providing estimates of current recreational use, the study provided for testing relationships between use and several related variables from which use estimates might be revised in future years. Daily and season-long records were obtained of the following variables:

1. Traffic-count record. Vehicles entering and leaving the parking lot were counted with two pneumatic-tube traffic counters installed near the parking lot entrance. Counters were read at 9:30 a.m. and at 6:30 p.m. on each of the 20 sample days and again at 9:30 a.m. on the following day. A season-long vehicle record was also obtained for the period May 1 to October 31, separately by weekend/holiday days and weekdays. Highly accurate records were obtained — average difference was less than 3 percent between the two counters for the 184-day season.
2. Bus ticket sales.
3. Visitor-count record. A Forest Service officer, stationed at the information desk in the exhibit hall and using a hand-held tally meter, counted all persons who entered the visitor center building.

Analysis and Results

Visit and use estimates for each sample day were calculated using the procedures already described. The next step was to generate season-long estimates of visits and use with a linear regression model. The general form of the model was $\hat{Y} = a(N) + b(X_s)$; where $\hat{Y}$ = season-long estimate of use, a = constant, N = number of days in the recreation season, b = regression coefficient, and X_s = season-long value of the indicator variable. The indicator variables used were traffic count, bus ticket sales, and visitor count at the visitor center building. Separate regression analyses were run to produce estimates of visits and use, by activity, based on each of the three indicator variables. To evaluate the effect of sample size on the accuracy of use estimates, two independent sets of estimates were generated for each variable — one based on the full sample of 20 days, the other based on the subsample of 12 days. Estimates of visits and use were generated for the entire recreation season and also for the day-of-week strata; i.e., weekend/holiday days and weekdays.

Relationships between visits and use, by activity, and the three indicator variables were quite strong and resulted in good estimates. Coefficients of determination (r^2) exceeded 0.95 for most relationships. Because estimates generated from the subsample were almost as strong as those from the full sample, statistics presented in the remainder of this report are based on the subsample of 12 days. Use estimates and confidence intervals, derived from traffic counts, bus ticket sales, and visitor counts, are shown in table 1. Regression equations from which these estimates were computed are shown in table 2.

Table 1.—Estimates of visits and use at the Brasstown Bald Visitor Information Center, Georgia, based on three separate indicator variables, May 1-October 31, 1968

Activity	Traffic count		Bus ticket sales		Visitor count	
	Estimate	Confidence interval 1/	Estimate	Confidence interval 1/	Estimate	Confidence interval 1/
	Visitor-days 2/	Percent	Visitor-days	Percent	Visitor-days	Percent
Number of visits						
Total for Brasstown Bald Site	77,128	±3.4	74,917	±10.2	76,022	±10.4
Visitor center building	57,049	±12.0	55,021	±13.5	55,523	(3/)
Number of persons						
Purchasing bus tickets	39,063	±10.4	37,672	(3/)	38,406	±11.0
Walking trail	29,444	±25.5	28,346	±31.1	28,266	±14.5
Visitor-days of use						
Bus	230	±10.6	222	±2.7	227	±12.4
Trail	1,249	±30.0	1,201	±36.1	1,193	±18.7
Visitor center building	2,528	±16.2	2,436	±16.5	2,460	±10.2
Other	2,975	±31.1	2,918	±38.4	2,966	±37.9
Total	6,982	±11.5	6,777	±19.6	6,846	±14.0

1/ Confidence interval at the 90-percent level of probability, expressed as percent of the estimates.

2/ Each visitor-day is recreation use which aggregates 12 person-hours. It may entail one person for 12 hours, 12 persons for 1 hour, or any equivalent combination of individuals or group use, either continuous or intermittent.

3/ Estimate is without sampling error as it represents a complete census.

Table 2.—Regression equations for updating estimates of recreation visits and use at the Brasstown Bald Visitor Information Center, Georgia, based on three indicator variables

Activity	Traffic count (X_1)	Bus tickets (X_2)	Visitor count (X_3)
Number of visits			
Total for Brasstown Bald Site	$-21.8571(N) + 0.9607(X_1)$[*]	$-19.0056(N) + 2.0815(X_2)$	$55.9228(N) + 1.1839(X_3)$
Visitor center building	$-55.0305(N) + 0.7952(X_1)$	$-56.0658(N) + 1.7344(X_2)$	Equivalent to X_3
Number of persons			
Purchasing bus tickets	$4.6559(N) + 0.4523(X_1)$	Equivalent to X_2	$39,1548(N) + 0.5620(X_3)$
Walking trail	$-74.2166(N) + 0.5102(X_1)$	$-71.3886(N) + 1.1011(X_2)$	$-42.0965(N) + 0.6486(X_3)$
Visitor-days of use			
Bus	$0.0827(N) + 0.0025(X_1)$	$0.0546(N) + 0.0056(X_2)$	$0.2820(N) + 0.0031(X_3)$
Trail	$-3.6611(N) + 0.0228(X_1)$	$-3.5127(N) + 0.0490(X_2)$	$-2.2735(N) + 0.0290(X_3)$
Visitor center building	$-2.2120(N) + 0.0347(X_1)$	$-2.3083(N) + 0.0759(X_2)$	$0.1672(N) + 0.0438(X_3)$
Other	$-3.2502(N) + 0.0423(X_1)$	$-2.4205(N) + 0.0893(X_2)$	$0.7901(N) + 0.0508(X_3)$
Total	$-9.0282(N) + 0.1023(X_1)$	$-8.2064(N) + 0.2200(X_2)$	$-1.0373(N) + 0.1267(X_3)$

[*] To revise the estimate of visitors for any year succeeding 1968, solve the formula after incorporating a new season-long traffic count for a similar 184-day season. For example: new hypothetical season-long axle count is 90,000; total visits = -21.8571 (184) + 0.9607 (90,000) = 82,441.

The more precise indicators of use were vehicle count and visitor count, but bus ticket sales also gave acceptable estimates. For several years following the 1968 site calibration, the only information needed to update use estimates is an accurate season-long record of one of the three indicators covering the same number of days (184) used during the calibration year.

Following is a summary of recreation use during the 1968 season at the Brasstown Bald Visitor Information Center, based on regression estimates from visitor-count records:

An estimated 76,022 visitors entered the parking lot during the 184-day season and spent 6,846 visitor-days[1] from the time they entered the lot until the time they left. Average number of persons per vehicle was 3.9. Average amount of use represented by each vehicle (time per vehicle × persons per vehicle) was 4.2 visitor-hours, indicating that each visitor stayed about 1 hour (4.2 hours ÷ 3.9 persons per vehicle = 1.1 hours). Estimates do not include use that occurred before 10 a.m. or after 6 p.m.

Approximately 56,000 of the 76,022 persons who visited the site spent time in the visitor center building. Estimated use at the visitor center building, including the exhibit hall, theater,[2] and observation deck, was 2,460 visitor-days or about one-third of total use. Average time in the visitor center was 29.2 minutes. More than 38,000 visitors rode the bus and about 28,000 walked the trail between the parking lot and visitor center building. Bus use accounted for 227 visitor-days, and trail use accounted for 1,193 visitor-days.

All other use (time spent waiting for the bus, picnicking near the parking lot, and waiting in vehicles) was about 3,000 visitor-days. Apparently about 20,000 persons never left the vicinity of the parking lot.

More than two-thirds of total seasonal use occurred on weekend and holiday days, although there were 129 weekdays and only 55 weekend/holiday days in the season. An average of 950 persons per day visited the site on weekends and holidays; an average of only 174 persons per day visited on weekdays.

Hourly distribution of use was also different by day of week. Weekday use was quite evenly distributed throughout the entire day; weekend and holiday use was more concentrated during midafternoon hours:

Hour of day	Weekend/holiday visitors *(Percent)*	Weekday visitors *(Percent)*
10:00	3	4
11:00	6	9
12:00	11	15
1:00	15	18
2:00	19	15
3:00	20	15
4:00	17	14
5:00	9	10

Weekend and holiday visitors also stayed longer than weekday visitors:

Length of stay on site *(Minutes)*	Weekend/holiday visitors *(Percent)*	Weekday visitors *(Percent)*
1-5	6	4
6-30	11	13
31-45	10	23
46-60	22	24
61-90	33	24
91 or more	18	12

Average time per visitor was 65.7 minutes on weekends and holidays and 58.6 minutes on weekdays.

About 85 percent of the visitors to the visitor information center were residents of Georgia. The remaining 15 percent were from 17 other states and a few foreign countries. Six percent were from Florida, 2 percent were from North Carolina, and 1 percent each were from Alabama, South Carolina, and Tennessee.

Discussion

Total cost of the sampling was $1,700, based on a recommended sampling intensity of 12 sample days, as itemized below:

Planning and training	$350
Data collection (12 days)	600
Equipment (includes traffic counters and automatic time-date clock)	300
Supplies (visitor cards and depository boxes)	100
Transportation	50
Data analysis	300

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[1] Each visitor-day is recreation use which aggregates 12 person-hours. It may entail one person for 12 hours, 12 persons for 1 hour, or any equivalent combination of individual or group use, either continuous or intermittent.

[2] Theater visits and use could not be estimated satisfactorily because of highly variable data. A season-long record, however, indicated that 10,166 persons saw the slide program, which accounted for 141 visitor-days of use.

The updating feature of the technique enables spreading the benefits and costs over several years. All that is needed to update use estimates for the next several years is an accurate season-long record of one of the use indicator variables. Although count of visitors entering the exhibit hall produced the best estimates, satisfactory estimates can also be obtained using vehicle counts or bus ticket sales. Total cost ($1,700) prorated over a 5-year period, for which use estimates can likely be updated, will average approximately $340 annually.

The Brasstown Bald Visitor Information Center represented a complex sampling situation and provided a good test of the sampling technique, although sampling costs were probably higher than would be encountered at other recreational sites. Sampling costs will vary with intensity of sampling and complexity of the site. The study resulted in a useful tool for obtaining estimates of current recreational use and provided for updating use estimates based on easily obtained indicators. The sampling procedures can be recommended for application at other visitor information centers and similar developments.

Cordell, Harold K., James, George A.,
and Griffith, Russell F.
1970. Estimating Recreation Use at Visitor Information Centers. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-69, 8 pp.

The paper decribes a pilot sampling technique for estimating use at visitor information centers. Procedures were tested on the Brasstown Bald Visitor Information Center in Georgia during 1968. Reliable estimates of use were obtained at moderate cost.

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Regeneration after Clearcutting in the Southern Appalachians

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Ralph M. Hooper

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Regeneration after Clearcutting in the Southern Appalachians

by

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Even-aged silviculture with its associated heavy harvest cutting has tremendous potential for regenerating upland hardwoods. However, even-aged silviculture must involve much more than a heavy harvest cut, for a heavy cut alone does not necessarily solve all of the problems of upland hardwood regeneration. In this paper a careful look is taken at a 46-acre tract of timberland 5 years after a complete clearcut. Although some questions as to the future of the area are unanswered, the tremendous growth rate and rapid stand development allow a preview of things to come.

The Study Area

The study area is located on Bent Creek Experimental Forest 10 miles south of Asheville, North Carolina. It is bisected by a permanent north-south stream and has two major aspects. On the west side of the stream, the land has an eastern aspect and is typical of much of the better forest land in the mountains. Before the harvest, the west side contained excellent yellow-poplar and northern red oak and some good chestnut oak. The east side of the stream has a westerly aspect and is mostly typical of poorer mountain land, although some of the east-side coves are capable of growing high-quality hardwoods. Much of the land on the east side of the stream contained a dense understory of mountain-laurel and rhododendron before the area was cleared.

The study area has a research history dating back to 1936, when it was subdivided into fifty 1-acre plots as part of a harvest cutting study. At that time five treatments were replicated 10 times on the 1-acre plots. The treatments ranged from no cutting to a diameter cut in which all trees above 14 inches were removed. The original plot boundaries have been retained, and the plots are identified by number. Almost 35 years have passed since the cutting, however, and no effects of the relatively mild treatments applied in 1936 have carried over to the regeneration on the area now. Four of the original plots have been deleted from this study because of road construction; therefore, results are now based on samples taken on 46 acres.

Methods

In 1963 and 1964, all commercial timber was cut by commercial loggers (fig. 1). The loggers removed an average of 24 sawtimber trees and 95 pulpwood trees per acre. The volume averaged 7,000 board feet of sawtimber and 10 cords of pulpwood per acre. Yellow-poplar, northern red oak, chestnut oak, and red maple made up most of the cut volume. The average stumpage price for sawtimber on this sale was relatively high for the period, indicating a large percentage of high-quality logs.

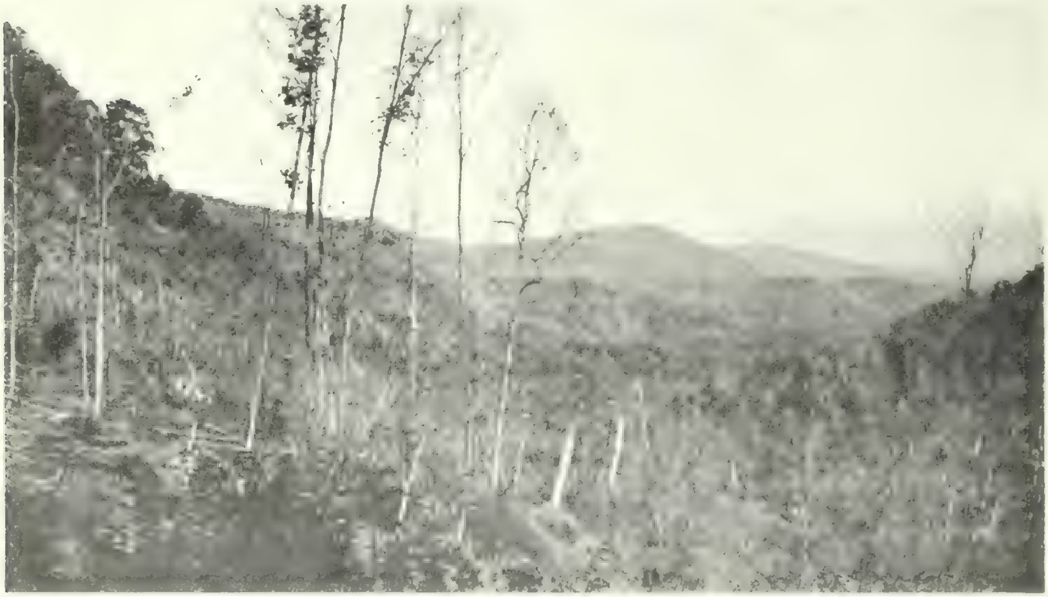


Figure 1.--A portion of the cutover area after commercial logging was completed but before any of the leftover material was removed.

After the commercial logging was completed, all leftover woody material over 4½ feet in height was cut by a contractor (fig. 2). Contract costs for this job were $35 per acre. The relatively high cost was due in part to the very dense rhododendron understory present on eight of the plots.

Regeneration on the area has been sampled three times in recent years. In 1963, just prior to logging, the advance regeneration was examined. A tally was made when the new stand was 2 years old, and another examination was made in the fall of 1968 when the stand was 5. In the first two samples, observations were made on milacre subplots in each 1-acre plot. The fifth-year examination was made on a 1/40-acre subplot in the center of each plot. Seedlings and sprouts less than $4\frac{1}{2}$ feet tall were not tallied because there was little likelihood that many would ever reach merchantable size. Seedlings and sprouts were judged to be either overtopped or free to grow and were listed accordingly. In the case of sprout clumps, no more than one stem in each clump was listed as free to grow.

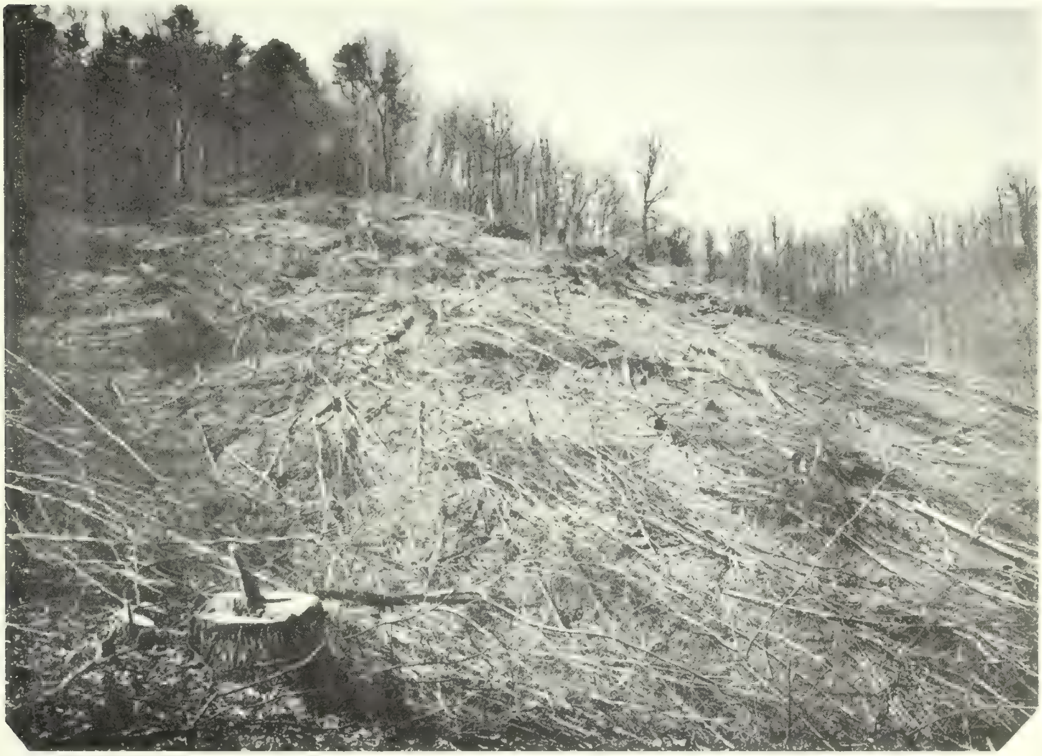


Figure 2.--The study area immediately after felling of leftover stems.

Results

Prior to logging in 1963, a large quantity of advance regeneration was present. These seedlings, which averaged 18,000 per acre, were very small and most were 1 year old or less, though there were some seedling sprouts. The most abundant species, red maple, averaged 11,000 seedlings per acre and was found on almost all the 1-acre plots. Yellow-poplar seedlings were found on only 14 plots and averaged 1,500 seedlings per acre on these plots. Northern red oak seedlings were found on 28 plots and averaged about 2,500 seedlings per acre on these plots. Chestnut oak, white ash, hickory, and other seedlings were present on some plots, but in much smaller numbers.

When Southern Appalachian timberlands are clearcut, the relatively stable, mature forest is suddenly transformed into a rapidly growing tangle of seedlings, sprouts, weeds, and vines. Only those stems that can endure the sudden exposure and take advantage of the increased supply of water, nutrients, and space can become a major complement of the new stand.

By 1965, 2 years after logging, the pattern of regeneration had changed considerably (fig. 3). The total number of seedlings present was still about 18,000 per acre, but the composition by species had little resemblance to that of the advance regeneration present 2 years earlier. Two species, yellow-poplar and sweet birch, the latter not even present in appreciable numbers in the 1963 sample, each totaled about 5,000 seedlings per acre and were found on almost all plots. Red maple seedlings were still abundant but averaged only 3,500 per acre. Northern red oak seedlings had also dropped in number and were found on only 12 plots. The presence of over 1,200 rapidly growing sprout clumps per acre was also changing the pattern of regeneration. Black locust, dogwood, and red maple clumps were present in the greatest number. Red maple and yellow-poplar sprout clumps were the tallest and occupied more space per clump than did other species.

In 1968 the stand was 5 years old. Though still a dense tangle, the new stand was beginning to show its true potential and also its problems (table 1). The stand contained an average of 370 desirable seedlings per

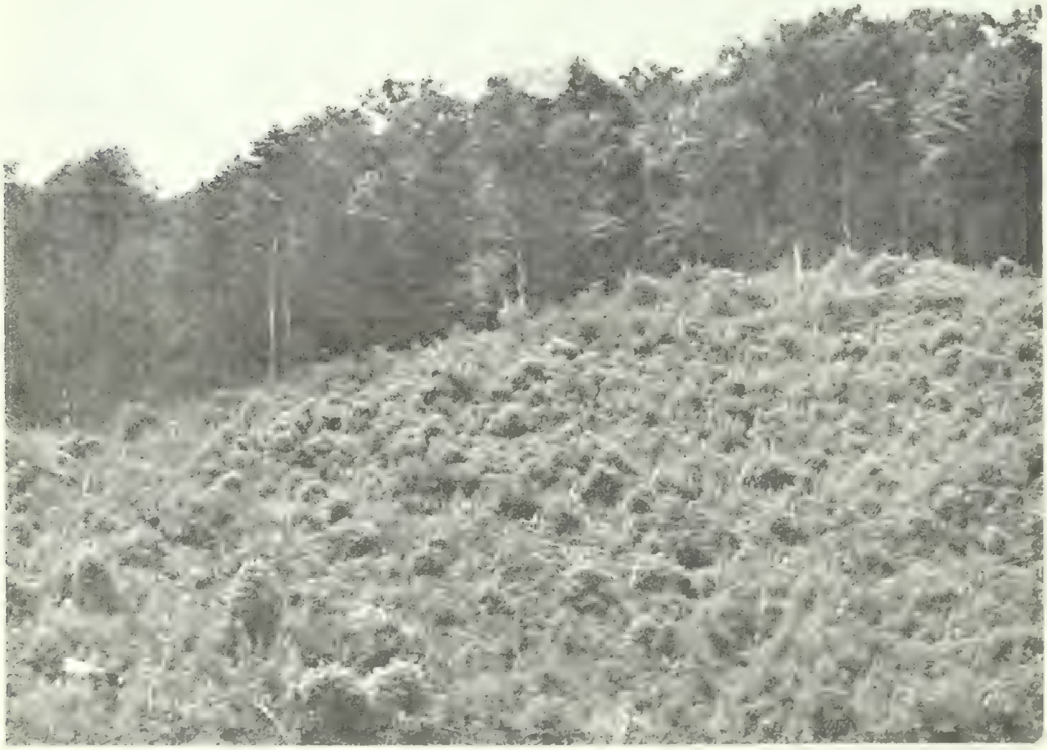


Figure 3.--Two-year-old regeneration. Note the large number of yellow-poplar and red maple sprouts.

Table 1.--Density of regeneration over $4\frac{1}{2}$ feet tall after 5 years

Species	Free-to-grow seedlings	Free-to-grow sprouts	Suppressed seedlings	Suppressed seedling sprouts	Sprout clumps
	- - - - - - - - - -	- - Number per acre - -	- - - - - - - - - -		
Yellow-poplar (*Liriodendron tulipifera* L.)	79	63	201	3	57
Sweet birch (*Betula lenta* L.)	226	35	740	2	41
Black locust (*Robinia pseudoacacia* L.)	0	247	0	122	23
Northern red oak (*Quercus rubra* L.)	20	12	40	0	17
Chestnut oak (*Quercus prinus* L.)	20	24	54	3	44
Black oak (*Quercus velutina* Lam.)	2	0	3	0	0
Other desirables[1]	23	34	43	6	41
Total desirables	370	415	1,081	136	223
Red maple (*Acer rubrum* L.)	4	58	24	3	65
Other undesirables[2]	24	137	166	73	249
Total undesirables	28	195	190	76	314
Grand total	398	610	1,271	212	537

[1] Other desirables include hemlock (*Tsuga canadensis* (L.) Carr.), white ash (*Fraxinus americana* L.), Fraser magnolia (*Magnolia fraseri* Walt.), black cherry (*Prunus serotina* Ehrh.), white oak (*Quercus alba* L.), and basswood (*Tilia americana* L.).

[2] Other undesirables include witch-hazel (*Hamamelis virginiana* L.), sourwood (*Oxydendrum arboreum* L. DC.), sassafras (*Sassafras albidum* (Nutt.) Nees), blackgum (*Nyssa sylvatica* Marsh.), dogwood (*Cornus florida* L.), and hickory (*Carya* spp.).

acre that were free to grow. These seedlings were sweet birch, yellow-poplar, white ash, and the oaks, and most of them have a reasonably good chance to survive and become a part of the future stand (figures 4 and 5). In addition to these free-to-grow seedlings, there were about 1,000 desirable seedlings per acre that were over $4\frac{1}{2}$ feet tall but were not free to grow. The future of these overtopped or suppressed seedlings is in doubt. Some will persist, but many will drop out soon unless something happens to the overhead competition.

The desirable seedlings on the area added to the potential of the stand, but the 168 desirable sprouts per acre (not including black locust sprouts) were easily the most impressive group of plants on the area. Many of these free-to-grow sprouts were yellow-poplar, and these stems already 20 to 30 feet tall will probably make up a major portion of the future stand (fig. 6). In addition to the yellow-poplar sprouts, there were also a few white oak, chestnut oak, and red oak sprouts that will probably

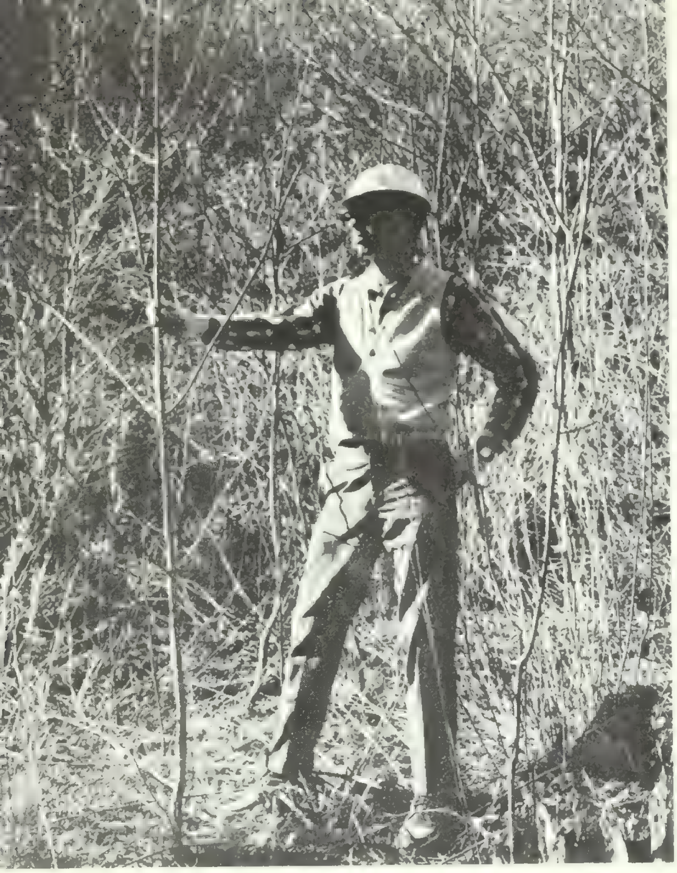
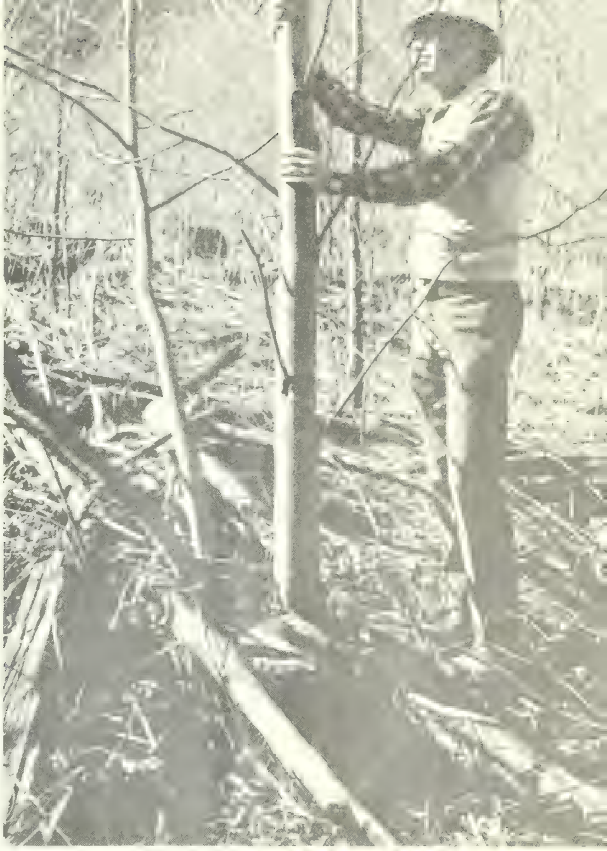


Figure 4.--A fine 5-year-old white ash seedling. The seedling is free from overtopping competition and has a good chance of becoming a high-quality crop tree.

Figure 5.--One of the many bright spots in the future of this area is this mixture of yellow-poplar and sweet birch seedlings.

Figure 6.--An outstanding example of a yellow-poplar sprout. This 5-year-old individual is about 5 inches d.b.h. and 35 feet tall.



continue to hold a position in the new stand. Besides the desirable free-to-grow sprouts, there were some suppressed seedling sprouts and many stems in sprout clumps that were not free to grow. As in the case of the suppressed seedlings, these suppressed sprouts will not become a major factor in the new stand unless something happens to the overtopping or surrounding competition.

Distribution of desirable plant material is perhaps as important as the total numbers of individuals present on the study area (table 2). Only six of the 1/40-acre subplots did not have either free-to-grow yellow-poplar sprouts or seedlings on them, and 14 subplots did not have free-to-grow birch. Locust sprouts were widely distributed and were found on almost all plots. Northern red oak was a real puzzle. Much of the study area contained fine mature northern red oak, and 28 subplots contained numerous red oak seedlings prior to harvest. Consequently, red oak was expected to make up a considerable portion of the future timber crop. However, red oak seems to be waging a continually losing battle with other species. Only a few subplots contain high-quality red oak stems, and these stems are usually much shorter than the competing vegetation.

The more than 700 desirable seedlings and sprouts per acre that were free to grow provide the study area with an adequate source of regeneration. However, the presence of many undesirable sprout clumps may affect the species composition and distribution of the stand. At best, undesirable sprout clumps will continue to occupy considerable area and will provide competition to the desirable crop trees for some time to come.

There were over 500 sprout clumps over $4\frac{1}{2}$ feet tall per acre in the 5-year-old stand. Some of these clumps contain desirable stems, but over half are of undesirable species. One of the greatest threats to the favorable development of this area is the presence of red maple sprout clumps on 28 plots. These clumps often contain 30 or more stems and

Table 2.--Frequency of regeneration over $4\frac{1}{2}$ feet tall after 5 years

Species	Free-to-grow seedlings	Free-to-grow sprouts	Suppressed seedlings	Suppressed seedling sprouts	Sprout clumps
	- - - - - - - - - - - -	- - - - - - Number	of subplots[1]	- - - - - -	- - - - - -
Yellow-poplar	29	26	33	4	24
Sweet birch	30	19	32	1	21
Black locust	0	39	0	32	25
Northern red oak	9	12	18	0	14
Chestnut oak	5	13	12	3	15
Black oak	2	0	2	0	0
Other desirables	15	22	20	5	26
Red maple	4	29	8	3	28
Other undesirables	11	37	29	16	43

[1] The entire sample is based on 46 subplots. Regeneration was recorded if at least one seedling or sprout of a species occurred on the subplot.

a single clump can completely occupy as much as 500 square feet of land (fig. 7). If these maple clumps continue to grow in height at a pace equal to or greater than the height growth of the desirable stems, much area can be lost to poor-quality red maple.

Locust sprouts and sprout clumps, though more numerous than red maple, do not offer as much competition. Few locust clumps completely occupy the site as the maple does; single locust sprouts do not interfere with the growth of other vegetation very much and are considered desirable. However, there are some plots on which locust has sprouted so prolifically that it has significantly affected the growth of other vegetation on the plot.

In the years immediately after the harvest cut, the presence of grape, rhododendron, laurel, fern, greenbrier, blackberry, and weeds played a significant role in the survival and growth of the woody stems. Now, after 5 years, these species continue to cover a considerable portion of the area. However, with the exception of grape and in a few cases laurel and rhododendron, these species will not affect the future of the stand.

Competition from grapevines has been a big factor in the development of the stand to date and will continue to influence both crop trees and the understory (table 3). In several places, grapevines have completely covered areas up to a quarter acre (fig. 8). As a result, these areas contain very few desirable stems and their future looks dim. Although the areas completely dominated by grapevines attract the most attention, the greatest overall damage has been and will be done by vines

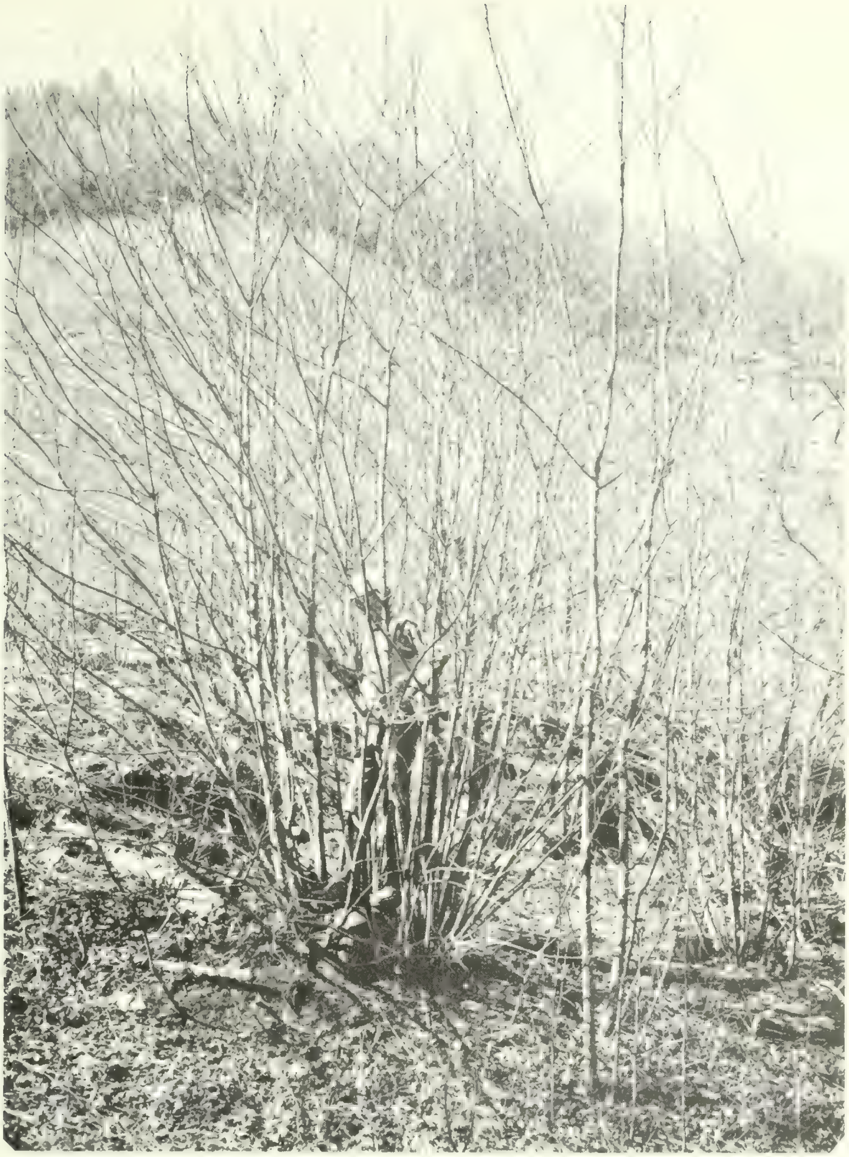


Figure 7.--Red maple sprout clumps, such as this healthy specimen, occupy large amounts of valuable growing space and may continue to cause serious problems for some time.

that intertwine about desirable crop trees and grow up with the trees (fig. 9). Grapevines are present on at least 21 of the 46 subplots, and they will continue to damage crop trees unless treatment is imposed.

Rhododendron and laurel were present in considerable quantities on a number of the plots. If the rhododendron and laurel had not been lopped off after logging, very little woody regeneration could have occurred on these areas. The rhododendron and laurel sprouts have not managed to keep up with the growth of other woody vegetation, however, and they are not likely to significantly affect future stand development.

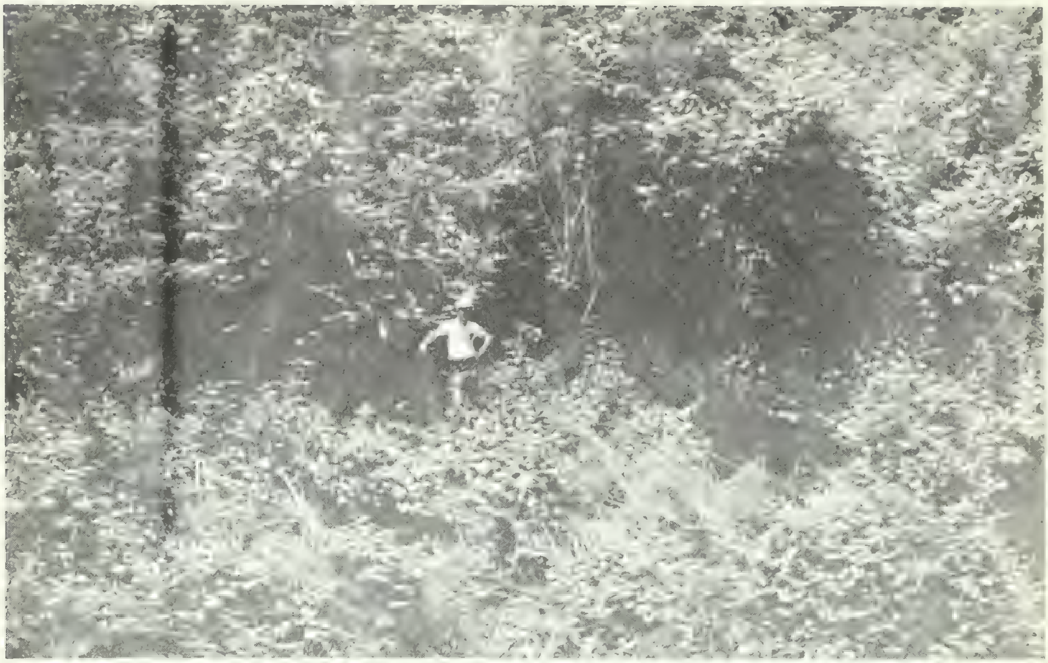


Figure 8.--Grapevines completely occupying an area to the exclusion of almost all woody vegetation.

Figure 9.--Grapevines riding down potential yellow-poplar crop trees.

Table 3.--Ground cover distribution on the 46-acre study area (excluding the dominant stand of trees)

Ground cover	Percent of ground covered	Number of subplots affected[1]
Seedlings under 4½ feet tall	14	30
Grapevine (*Vitis* spp.)	17	21
Greenbrier (*Smilax* spp.) and blackberry (*Rubus* spp.)	5	13
Ferns (*Polystichum* spp.)	16	27
Mountain-laurel (*Kalmia latifolia* L.) and rhododendron (*Rhododendron maximum* L.)	6	12
Weeds and grass	22	29
Open	20	36

[1] The entire sample is based on 46 subplots.

Discussion

The current condition of the study area is ample evidence that a complete clearcutting can be an effective means of regenerating upland hardwoods. The presence of many free-to-grow desirable stems is very encouraging. Also encouraging is the fact that after 5 years some seedlings are 10 to 15 feet tall and many sprouts are 30 feet tall.

The presence of undesirable sprout clumps and overtopped or suppressed seedlings will continue to cause some concern. Although the total number of desirable stems is adequate, distribution of crop trees in some places is not optimum with respect to spacing and species.

When faced with sprout clumps and overtopped or suppressed seedlings on similar areas, many forest managers will immediately propose an intense cleaning. We, on the basis of current information, do not recommend that such areas be cleaned. The cost of a properly applied cleaning will be high and the returns questionable. The results of a cleaning, particularly in a stand as young as this one, may be very unsatisfactory. Even though released by cleaning, some stems will not respond and will never make high-quality crop trees. Other stems would have made crop trees anyway and will benefit little from the cleaning. If it is done at all, cleaning should be reserved for 10- to 15-year-old stands without adequate free-to-grow regeneration on highly productive land. An important exception to this rule is the removal of grapevines from obvious crop trees.

Even-aged silviculture with complete clearcutting is obviously not a panacea. It is, however, the most effective technique that has been used in the Southern Appalachians for hardwood regeneration. There is a good chance that further modification could improve the reliability of the even-aged system and allow increased control over species composition. Modification is needed to develop techniques for increasing the percentage of hard-to-regenerate species such as northern red oak. Further control of the early stand might also be accomplished through more effective use of intermediate cuts and preharvest treatments that would eliminate undesirable individuals or species.

One final point: A critical step in the procedure is the control of leftover material after commercial logging is complete. If the leftover material is not controlled, it will occupy the site and will accordingly reduce the productivity of the area for many years to come. If proper followup procedures are not feasible, then the harvest should be postponed.

McGee, Charles E., and Hooper, Ralph M.
1970. Regeneration after Clearcutting in the Southern Appalachians. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-70, 12 pp.

Remeasurements on a 50-acre area in the Southern Appalachians indicate that a complete clearcutting has tremendous potential for regenerating high-quality hardwoods. Five years after commercial logging and cutting of leftover material, over 500 desirable seedlings and sprouts per acre were free to grow. Yellow-poplar, sweet birch, northern red oak, chestnut oak, and white ash made up the bulk of the desirable stems. On the other hand, over 60 red maple sprout clumps per acre were present; these completely occupied large areas. Grapevines were present on many plots and will continue to impede growth and degrade the quality of some crop trees. Firm decisions as to the need for precommercial cultural measures cannot be made at this time. There is a good possibility, however, that no treatment will be needed except grapevine control on crop trees.

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Publications of the Southeastern Forest Experiment Station 1964-1968

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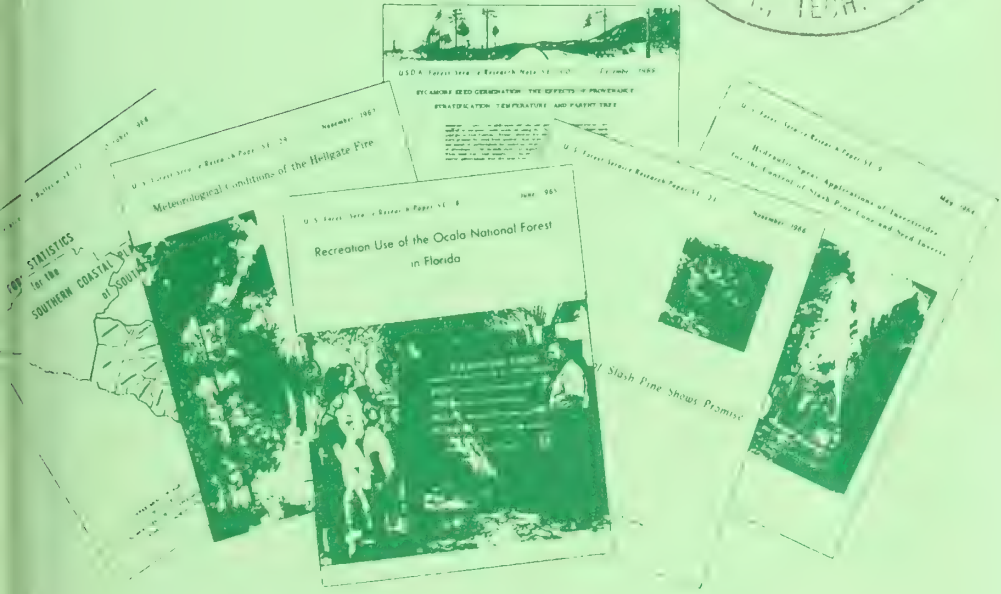

Meteorological Conditions of the Hellgate Fire

Recreation Use of the Ocala National Forest in Florida

Forest Statistics for the Southern Coastal Plain

Sycamore Seed Germination: The Effects of Provenance, Stratification Temperature, and Parent Tree

Hydraulic Spray Applications of Insecticides for the Control of Slash Pine Cone and Seed Insects

Slash Pine Shows Promise

Forest Service, U. S. Department of Agriculture
Southeastern Forest Experiment Station
Asheville, North Carolina

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Aldrich, R. C., and Drooz, A. T.

1967. Estimated Fraser fir mortality and balsam woolly aphid infestation trend using aerial color photography. Forest Sci. 13: 300-313.

A stratified-systematic sample of photo plots was used to estimate the number of dead *Abies fraseri* (Pursh) Poir. per acre of defined type on 22,000 acres near Mt. Mitchell, North Carolina. The sample design included 215 one-acre plots stratified in 1:7920 scale aerial color photographs by mortality classes. Fir mortality and live spruce and fir were counted on the photos using 4.5 power stereoscopic magnification. Thirty photo plots were located on the ground to measure aphid populations and to count fir mortality and live spruce and fir. From the photo and ground counts of mortality and live trees, regression lines were developed to adjust photo estimates made from the larger photo sample. The best relationship included dominant, codominant, and intermediate trees ($r=0.7$). The first year adjusted estimate of dead Fraser fir per acre was 13.9 ± 0.8 trees. Each year the 215 photo plots were transferred to new color photos for re-estimates which showed a definite upward trend for 4 years and reached 21.3 ± 1.0 dead fir per acre in 1963. Photo plots in the 1-50 percent mortality range were the best indicators of trend. Since balsam woolly aphid damage is accumulative, equations were developed to compute the index of accumulated fir mortality on a rating scale of 0-4. The survey design used in this study was three times as efficient as a simple random sample of equal intensity. The cost of the original survey was 11 cents per acre and each resurvey 5 cents per acre.

Altobellis, A. T., and Hough, W. A.

1968. Controlling palmetto with fire and herbicides. Ga. Forest Res. Counc. Res. Pap. 52, 4 pp.

Saw-palmetto (*Serenoa repens* (Bartr.) Small) is a major component of the understory vegetation in many stands of slash-longleaf pine from Louisiana to South Carolina. The purpose of the study reported here was to use prescribed fire and 2,4,5-T in an effort to control this species growing under a forest stand.

Different combinations of burn and spray applications, along with two concentrations of herbicide—2.75 and 5.5 pounds acid equivalent per acre (AE/A)—and two carriers—oil and water—were tested on palmetto growing on the Waycross State Forest in south Georgia. The best control of palmetto was obtained from the combination of two summer sprays (July 1963 and 1964) with two burns (February 1964 and July 1965). A spray of 5.5 pounds AE/A in water gave the best results, killing 61 percent of the plants and reducing the height of those remaining by 25 inches. After treatment a large increase in grass was observed on the test plots.

Cost of this treatment could be as high as $15.00 per acre. Although this cost is higher than burning alone, the benefits derived from this combination treatment may justify the expenditure. Not only is access to the stand improved but grazing potential and tree growth may be increased because of reduced competition. Also, prescribed burning for reduction of fire hazard would be effective for a long period after this treatment because of the more permanent reduction in palmetto fuel.

Amman, G. D.

1966. *Aphidecta obliterata* (Coleoptera: Coccinellidae), an introduced predator of the balsam woolly aphid, *Chermes piceae* (Homoptera: Chermidae), established in North Carolina. J. Econ. Entomol. 59: 506-508.

Aphidecta obliterata (L.) was introduced into North Carolina from Germany in 1960 to aid in control of the balsam woolly aphid, *Chermes piceae* Ratzeburg, which has killed more than ¼ million Fraser fir trees in the Mt. Mitchell area. The beetle was recovered each year since its release, except in 1961, and appears to be established.

———

1966. Some new infestations of the balsam woolly aphid in North Carolina, with possible modes of dispersal. J. Econ. Entomol. 59: 508-511.

The aphid reached Mt. Sterling in the Great Smoky Mountains National Park prior to 1958, Roan Mountain in 1958, and Grandfather Mountain in 1959. Of the possible dispersion agents, it is concluded that wind is the most likely.

———

1967. Effect of minus 29° F on overwintering populations of the balsam woolly aphid in North Carolina. J. Econ. Entomol. 60: 1765-1766.

Populations of the balsam woolly aphid were examined in March 1966 for mortality after a temperature of minus 29° F. These observations were compared with similar observations for March 1964 after a temperature of minus 16° F. In the two plots observed, mortality in 1966 was 16 and 24 percent greater than in 1964.

———

1968. Effects of temperature and humidity on development and hatching of eggs of *Adelges piceae.* Ann. Entomol. Soc. Amer. 61: 1606-1611.

Effects of (1) a range of constant temperatures and humidities, (2) immersion in water, (3) desiccation, and (4) freezing temperatures on development and hatching of eggs and survival of crawlers were determined for the balsam woolly aphid, *Adelges piceae* (Ratzeburg).

The developmental-hatching threshold was established at between 5° and 7° C. and the upper limit for development at about 30° C. Hatching success was best and crawler life was longest at intermediate temperatures. Humidity had a pronounced effect on the incubation period, on hatching success, and on survival of crawlers. Immersion of eggs in water had no effect on subsequent hatching, but desiccation caused a reduction in hatch. Freezing had little effect on subsequent hatching of eggs unless the temperature was below $-8°$ C. A rectilinear relationship existed between developmental rates and intermediate temperatures (excluding extreme high and low temperatures). The slope of the developmental-rate curve was modified by the effect of humidity. These findings are discussed in relation to observations of temperature and humidity in the field.

——— **and Speers, C. F.**

1964. Release of predators of the balsam woolly aphid in North Carolina. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-32, 4 pp.

Three species of balsam woolly aphid predators imported from Germany in 1959 and 1960 have become established in North Carolina. None of the 13 aphid predators introduced from India and Pakistan and two from Germany in 1959 and 1960 have been recovered since their release.

Amman, G. D., and Speers, C. F.

1965. Balsam woolly aphid in the Southern Appalachians. J. Forest. 63: 18-20.

Life history of balsam woolly aphid and nature of injury to Fraser fir. Discusses Fraser fir mortality, remaining stand locations, and insecticidal and biological control of the aphid.

——— **and Speers, C. F.**

1965. Progress in biological control of the balsam woolly aphid in North Carolina. South. Lumberman 211(2632): 147-149.

Report of predator introductions.

——— **and Talerico, R. L.**

1967. Symptoms of infestation by the balsam woolly aphid displayed by Fraser fir and bracted balsam fir. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-85, 7 pp.

Stands of bracted balsam fir in Shenandoah National Park in Virginia and Fraser fir near Mt. Mitchell in North Carolina were examined to determine differences in symptoms displayed by the two species to infestation by the balsam woolly aphid. The principal injury to bracted balsam fir was gouting of nodes and buds. Dying of branches began at the top of the tree and proceeded toward the base. However, bracted balsam fir trees survived several years of aphid infestation. Fraser fir was injured primarily from stem infestations by the aphid. Mortality of branches began at the base of the crown and proceeded to the top. Fraser fir trees died after a short period of aphid infestation.

Anderson, L. O., and Smith, W. R.

1965. Houses can resist hurricanes. Forest Prod. Lab., U. S. Forest Serv. Res. Pap. FPL-33, 48 pp.

The ability of wood-frame house construction to withstand hurricanes and earthquakes is indicated, and recommendations for building superior wood structures are made. Details of construction, including fastenings, are shown. Existing and improved building requirements are covered, as well as two systems utilizing embedded poles and timbers.

Anderson, W. C.

1964. What is price reporting, what is it good for, and how does it work? Amer. Pulpwood Assoc. Tech. Pap. 63-61(8.123): 15-17.

The nature and workings of price reporting are reviewed, including consideration of the elements involved in an "ideal" system. Several ways price reporting may benefit pulp companies are suggested.

Applefield, Milton

1964. Polyethylene and Kraft paper wrappings for protecting kiln-dried lumber stored in the open. Hardwood Res. Counc. Rep. 12, 5 pp.

Polyethylene film and water-repellent Kraft paper were evaluated for effectiveness as covers for kiln-dried lumber stored outdoors. Although these materials did not exclude the entrance of moisture in either liquid or vapor form, moisture pick-up in the test piles was not excessive for the first 40 days.

———

1965. Sources of lumber for furniture plants in North Carolina, 1963. Hardwood Res. Counc. Rep., 5 pp.

Over 347 million board feet of lumber (including particle board) were purchased during 1963. Of this volume, 304 million feet came from domestic sources, with about 42 percent from sawmills within the State.

Applefield, Milton

1968. Building code regulations governing wood use in Georgia's six most populous cities and counties. Ga. Forest Res. Counc. Res. Pap. 58, 11 pp.

A pilot study was made of building code regulations that influence the use of selected wood products and applications in general building construction for Georgia's six largest cities. The regulations and their influences on design, construction costs, and use restrictions are discussed.

———

1968. Impact of building codes on wood use for single-family house construction in Georgia. South. Lumberman 217(2704): 163-166.

Various regulations affect the use of wood building products. Prominent among these controls are building codes. Variation in code requirements, interpretation, and enforcement result in a diversity of restrictions for wood use. Some effects of code requirements on selection and use of certain wood products were revealed in a study of 33 cities and 29 counties in Georgia.

——— **and Bois, P. J.**

1966. Thickness variation of hardwood lumber produced in 1963 by circular sawmills in North Carolina. Hardwood Res. Counc. Rep., 5 pp.

Thirty-two truckloads of rough green hardwood lumber were sampled in the piedmont areas of North Carolina for thickness variation. Results showed that almost 38 percent of the sample lumber was mismanufactured.

Asher, W. C.

1964. Electrical potentials related to reproduction and vigor in slash pine. Forest Sci. 10: 116-121.

Electrophysiological techniques show promise as valuable research tools in tree physiology. Electrical potential measurements on slash pine branch material give significant correlations with presence or absence of female flower buds and with geographic distribution of this species. Studies on slash pine flower scales showed that the electrical potential of the nucellus with respect to the dorsal surface of the ovule reversed polarity upon pollination.

———

1964. A formula for estimating slash pine seed yields. J. Forest. 62: 37-39.

Estimates of sound seed yields per bushel of cones are necessary in planning seed collection programs. Seed yield of slash pine can be estimated by means of the regression equation, $Y = 12.7 + 9.31X$, where Y = estimated sound seed per cone and X = number of sound seeds exposed by slicing the cone longitudinally in half. This formula has wide applicability in Georgia and Florida. The correlation coefficient, r, is 0.85 and is highly significant. In application, about 5 cones each from 25 to 30 trees are halved longitudinally and the number of sound seed exposed entered as X in the equation. Estimated sound seed yield in pounds per bushel of cones are tabulated for large, medium, and small seeds and several different cone sizes.

———

1968. Response of pine seedlings to mechanical stimulation. Nature 217(5124): 134-136.

A discrete, consistent electric potential change was found to be associated with flexure of needle fascicles on seedlings of *Pinus taeda* L. and *P. elliottii* var. *elliottii* Engelm. While the source and mechanism of production of these potential changes is obscure, it is suggested that such changes in response to mechanical displacement might be characteristic of certain plant structures.

Barber, J. C.

1964. How much is forest genetics helping the forester by increasing growth, form, and yield? Seventh South. Conf. Forest Tree Impr. Proc. 1963: 16-20.

Heritability estimates for high growth, form, and yield of wood are summarized for southern pines.

——— 1964. Inherent variation among slash pine progenies at the Ida Cason Callaway Foundation. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-10, 90 pp.

Two open-pollinated slash pine progeny tests were examined at ages up to 9 years from seed. Data analyzed included height, d.b.h., pruning height, stem straightness, forking, fusiform rust infection, and survival. Branching characteristics and bark thickness were also examined. Differences among progenies were tested and correlation values determined between many traits. Narrow-sense heritability values were calculated for height (0.03 – 0.37), d.b.h. (–0.22 – 0.37), pruning height (0.36 – 0.64), and crown width (0.16 – 0.19). Silvicultural application of information was discussed, and the importance of proper progeny test design.

——— 1965. Seed, pp. 3-9. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Emphasizes the importance of collecting pine seed from the proper geophysical and altitudinal area and from genetically suitable trees. Correct handling, storage, and extraction procedures are necessary so that the seed will not be damaged.

——— 1966. The use of automatic data processing in tree improvement and genetics program. Forest Sci. 12: 214-224.

The methods given are designed to use equipment available in most industries and large governmental offices.

——— 1966. Variation among half-sib families from three loblolly pine stands in Georgia. Ga. Forest Res. Counc. Res. Pap. 37, 5 pp.

Initial survival and 5-year total heights and fusiform rust infection are reported for 11 half-sib families from each of three stands representing a NW-SE transect across Georgia. Significant differences were found between sources for the three characters. The southern source survived poorest; the northern source grew slowest; and the local source had lowest rust infection. Differences among families within sources were greater than differences between source means.

——— **and Dorman, K. W.**

1964. Clonal or seedling seed orchards? Silvae Genet. 13: 11-17.

Data are presented on oleoresin yield, wood specific gravity, and stem volume in full sibs of slash pine with correlations and the range of variation. Also, measurement data from a 7-year-old slash pine seedling seed orchard for form, height growth, and disease infection are given. These data, plus problems in length of time required for establishment and those in connection with progeny testing for seed certification, are discussed from the standpoint of seed orchard establishment. It is concluded that the advantages claimed for seedling seed orchards over clonal orchards in some theoretical discussions cannot be realized when tree species are involved that are inherently variable in several economically important traits.

Barber, J. C., and Dorman, K. W.

1967. Forest genetics publications by the Southeastern and Southern Forest Experiment Stations, 1962 through 1966. South. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SO-28, 23 pp.

Annotated bibliography of papers on forest genetics, forest tree breeding, and several closely related fields.

Barnes, R. L.

1965. Relations between nitrogen content and flowering in pine. (Abstr.) Soc. Amer. Forest. Proc. 1964: 47.

Recent studies indicate that analyses of soluble nitrogen fractions in the woody twigs provide a better evaluation of the nitrogen status of pines than the previously used determinations of total foliar nitrogen content. A study in an intensively cultured "orchard" of slash pine in Florida is evaluating changes in nitrogen status of the trees as a result of nitrogen fertilization, as well as relating nitrogen responses and flowering. Differences in arginine and total amino acid content due to treatment are apparent, as are differences in arginine content of eight clones selected for differences in past flowering.

——— **and Bengtson, G. W.**

1968. Effects of fertilization, irrigation, and cover cropping on flowering and on nitrogen and soluble sugar composition of slash pine. Forest Sci. 14: 172-180.

Effects of nitrogen fertilization, irrigation, and cover-cropping vs. disking on nitrogen and soluble sugar composition and on flowering of eight clones of slash pine (*Pinus elliottii* Engelm.) were studied. Fertilizing with ammonium nitrate increased free arginine, total free amino acids, and total nitrogen of the twigs; and total nitrogen of the needles. Fertilizing also doubled female flower production. Irrigation decreased total foliar nitrogen, and increased male flowering as an interaction with clones. Cover-cropping with a legume (hairy indigo) increased arginine content and decreased soluble sugar content of the twigs, and interacted with irrigation in affecting female flowering. There were highly significant differences among clones in female and male flowering, all measures of nitrogen content, and soluble sugar content. There were also several significant interactions between clones and treatments in affecting flowering and nitrogen composition.

Barrett, J. P., and Bengtson, G. W.

1964. Oleoresin yields for slash pines from seven seed sources. Forest Sci. 10: 159-164.

Evaluations of the oleoresin-yielding potential of *Pinus elliottii* var. *elliottii* from a number of geographic sources planted in Louisiana 200 miles west of natural range of the species. Seed sources ranging from South Carolina to Florida and westward to Louisiana did not differ in oleoresin yield under microchipping, nor in viscosity and exudation pressure of the resin. Individual trees, by contrast, varied greatly—their productivity being correlated with diameter, length of live crown, ratio of crown length to total height of tree and viscosity of resin.

Bay, R. A., and Klawitter, R. A.

1964. What's new in wetland hydrology. Soc. Amer. Forest. Proc. 1963: 175-177.

Present classification schemes for wetland areas are based on ecological or morphological soil characteristics. From a watershed manager's viewpoint, it is necessary to have a classification scheme based on physical and hydrologic characteristics. Such a scheme would prove invaluable for planning water control, cutting methods, conversion, or water impoundments. Work on this type classification has recently been started.

Beck, D. E.

1964. International ¼-inch board-foot volumes and board-foot/cubic-foot ratios for Southern Appalachian yellow-poplar. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-27, 4 pp.

The practice of carrying growth and yield data on a cubic-foot basis for management purposes and converting later to a board-foot basis for timber sales requires board-foot/cubic-foot converting ratios. However, most existing board-foot and cubic-foot volume tables have been constructed independently and ratios derived from them are likely to form erratic and illogical patterns. For this reason International ¼-inch board-foot volume tables for yellow-poplar have been developed by analysis of board-foot/cubic-foot ratios.

——— **and Olson, D. F., Jr.**

1968. Seed production in Southern Appalachian oak stands. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Note SE-91, 7 pp.

Acorn production in mixed oak stands of different densities varied considerably among stands, years, and species. Density had no effect on total acorn production. Although numerous acorns were initiated each year, the majority either failed to develop fully or were damaged by insects and animals.

Belanger, R. P.

1964. A study of 2,4,5-T formulations and carriers applied with a portable mist blower. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-23, 4 pp.

Weed hardwoods in the lower Piedmont occur in clumps, patches, and as extensive contiguous areas. Control methods to use depend upon the pattern of occurrence of weed species, size of the trees, and species composition. Mist blower application of herbicides is suited to any pattern of weed tree distribution, provided the trees are not over 20 feet tall. Experiments with different 2,4,5-T formulations killed from 40 to 70 percent of the trees in the usual weed species compositions found in the lower Piedmont. Among different species, topkill ranged from 7 percent to 92 percent depending upon formulations used and susceptibility of species to the herbicide. There are strong indications that 2,4,5-T mixed with undiluted oil carriers gives a greater kill of the predominating species than when mixed with a water-oil carrier.

——— **and Brender, E. V.**

1968. Influence of site index and thinning on the growth of planted loblolly pine. Ga. Forest Res. Counc. Res. Pap. 57, 7 pp.

At 19 years of age, 6- by 6-foot planted loblolly pine will support 14 to 44 cords of merchantable wood per acre in the Georgia Piedmont, depending upon the site index of the land. Mechanical methods of row thinning or thinning from above expose such stands to severe damage from glaze storms, which are common in this area. Average periodic annual growth in plots thinned mechanically at age 19 ranged from ½ to ¾ cord per acre; those plots thinned selectively or from below grew annually from 1 to 1-2/5 cords per acre. Early mortality from fusiform rust and later mortality from *Fomes annosus* seem to be strongly influenced by site index.

Belcher, E. W.

1968. Repellent-coated seed of loblolly pine can be stratified. USDA Forest Serv. Tree Planters' Notes 19(2): 10-12.

Five mixed lots of loblolly pine seed were used to evaluate pregermination treatments on repellent-coated and uncoated seed. The treatments were: (1) no treatment — stored at 20° F. in sealed containers, (2) subjected to high humidity for 30 days at 38° F., (3) overnight water soak at 70° F., (4) stratified in damp moss for 30 days at 38° F., and (5) stratified in polyethylene bags for 30 days at 38° F. In this treatment the seed were not soaked in water before stratifying, but a handful of damp moss was added to one corner of the polyethylene bag. Both coated and uncoated seed were stored for varying periods of time before pregermination treatments.

Neither total germination nor germination speed were affected by the length of storage. All repellent-coated seed possessed a seed dormancy when removed from storage; whereas, no dormancy was noted in the uncoated seed. This dormancy was overcome by treatments 4 and 5.

——— **and Neel, W. W.**

1967. Effect of selected systemic insecticides on loblolly pine seed germination. Ga. Forest Res. Counc. Res. Pap. 49, 4 pp.

At the West Virginia University, an unstratified loblolly pine seed lot was divided and each sublot given one of 10 systemic insecticide treatments. Following treatments, the seed samples were sent to the Eastern Tree Seed Laboratory for standard laboratory tests to evaluate their effect on germination. Chemicals not harmful to unstratified seed were applied at the same rate and at ½, 1, 2, and 4 times that rate to stratified seed.

Of the 10 chemicals applied to unstratified loblolly pine seed at 2 ounces per 100 pounds of seed, five proved detrimental to germination and one of the remaining chemicals was withdrawn from use. Of the remaining four chemicals used on stratified seed, no significant differences were noted in the germination of chemically treated stratified seed when compared to an untreated control. Increases in dosage of these chemicals showed a trend of decreased germination, a slower germination rate, and an increase in abnormal germination.

Bengtson, G. W.

1965. Progress, problems, and plans in physiological research conducted in an intensively cultured orchard of slash pine. (Abstr.) Soc. Amer. Forest. Proc. 1964: 47.

An intensively-cultured slash pine orchard of 24 clones of known oleoresin-yielding potential has been subjected to fertilization, irrigation, and ground cover manipulation since 1959. In terms of height and diameter growth, fertilizers have had no effect to date. Irrigation increased stem growth, but only when the ground cover was left undisturbed. The most significant results concern tree flowering in response to treatment.

——— **McGregor, W. H. D., and Squillace, A. E.**

1967. Phenology of terminal growth in slash pine: some differences related to geographic seed source. Forest Sci. 13: 402-412.

Observations were made on the terminal growth phenology of 6-year-old slash pine (*Pinus elliottii* Engelm.) from 14 geographic sources growing in a plantation in northeastern Florida. Differences in time of beginning of terminal growth were minor. But provenances from the north-central portion (optimal climate zone) of the species grew more rapidly during the early portion of the season than did those from the extreme northern or southern areas. Sources from peninsular Florida made somewhat more growth than other provenances in late summer. Total growth during the year was greatest among sources from the north-central region.

ennett, F. A.

1964. Growth, yield, and diameter distributions in slash pine plantations. (Abstr.) Assoc. South. Agr. Workers Proc. 1964: 165-166.

Diameter distributions in slash pine plantations are shown to be highly correlated with mean diameter. This in turn reflects the strong effect of density, and increasing competition, on the shifting distributions. Diameter distributions are used to illustrate the effect of initial spacing on the first thinning and the residual stand.

1964. Predicting the number of trees suitable for chipping in slash pine plantations in the middle coastal plain. AT-FA J. 26(5): 14-15, 17. Also in Nav. Stores Rev. 73(11): 6-7.

Knowledge of the number of naval stores faces available some time in advance of the cupping operation would greatly aid landowners and producers in planning and scheduling their turpentining operations. A prediction equation derived through regression analysis of available data permits forecasts of the number of trees per acre 9 inches and larger in a slash pine plantation.

Results of the analysis show that spacings below 10x10 feet will not produce trees of naval stores size in quantity by age 20, except on the best sites. On the best sites, 75 feet or better, on a 25-year basis, the number of trees 9 inches and larger in narrow spacings may be as great, or greater, than that in the wider spacings. However, potential gum production is not as great because the trees have smaller crown ratios and are smaller in diameter. Although a program of selective cupping can be started in the wider spacings at a relatively young age, this is not possible in the close spacings. Short rotations without intermediate thinnings are also well suited to gum production in the wider spacings for the 4 or 5 years preceding the harvest cut because of the large number of faces available per acre. Only the wider spacings permit this type of management.

1965. Diameter distributions in slash pine plantations. Soc. Amer. Forest. Proc. 1964: 234-237.

Several approaches are used to investigate diameter distributions in slash pine plantations. Distributions are established as a function of mean diameter. These data help in planning naval stores operations and thinning schedules.

1965. Growth and yield of planted slash pine, pp. 221-241. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Height growth patterns of planted slash pine are presented, and cubic yields are discussed in relation to age, site, and density. Growth is compared on old fields and on untilled, cutover forest land.

1965. Harvesting slash pine, pp. 125-129. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Harvesting methods—or more accurately, reproduction methods—used in plantations will be basically the same as those employed in natural stands. Usually the mode of reproduction will be one of the four standard methods prevailing in the United States: selection, seed tree, shelterwood, or clear cuttings.

Bennett, F. A.

1965. Planning silvicultural research at Olustee. AT-FA J. 28(3): 13-14

The program of work includes study of: (1) effective means o naturally regenerating slash and longleaf pine; (2) the developmen of methods for not only stimulating but also regulating seed production; (3) the determination of optimum site preparation treatments by site and species categories, as well as the development of successful seeding methods with a high degree of control over stocking distribution; and (4) establishment of growth and yield patterns in relation to age, site, and density for both thinned and unthinned stands.

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1965. Thinning slash pine, pp. 111-118. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

A thinning is a cutting made in an immature stand to increase the growth of the residuals and the total production of the stand. Cleanings, improvement cuttings, and salvage cuttings are considered separate and distinct silvicultural operations. However, the first thinning in a plantation will probably be a combination of the various intermediate cuttings. Thinning objectives will dominate, but objectives of the improvement cut and the salvage cut will prevail to some extent.

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1966. Construction and use of volume and yield tables, pp. 17-29. *In* Measuring the southern forest. La. State Univ. Sch. Forest., Fifteenth Annu. Forest. Symp. Proc. 1966.

Construction of volume tables by the least squares regression technique is explained. Construction and use of yield tables for unthinned stands, both plantations and natural stands, are discussed, and regression models for the two types of stands are compared. Differences in the effect of the density variable between the two types of stands are illustrated.

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1966. Natural stand versus plantation management in southern pine. Amer. Pulpwood Assoc. Tech. Pap. 66-6: (2.55): 18-21.

Cordwood yields from site-prepared and planted forest sites can be expected to be 30 to 50 percent greater than from unprepared and naturally regenerated forest sites, assuming site preparation will increase site index by 5 feet at age 25. There will be a greater difference in board-foot yields. Natural stands precommercially thinned will require a longer period to equal production from site-prepared and planted stands. If production were equalized between the two types of management, the much greater certainty of stand establishment by planting offers a big advantage.

——— **and Clutter, J. L.**

1968. Multiple-product yield estimates for unthinned slash pine plantations—pulpwood, sawtimber, gum. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-35, 21 pp.

If the objective of forest management is to maximize cash returns, the forest manager must be able to determine the optimum density and rotation age; these determinations require techniques for predicting multiple-product yields for various age—site—density schedules. This paper presents multiple-product yield estimates for slash pine plantations that were obtained by constructing a family of frequency curves that define the relative proportion of trees in each diameter class as a function of age, site, and density. Included are estimates of board-foot, pulpwood, and gum yields, singly and in combination. Returns for single products and the various combinations of products are also included.

Berry, C. R.

1964. Differences in concentrations of surface oxidant between valley and mountaintop conditions in the southern Appalachians. J. Air Pollut. Contr. Assoc. 14: 238-239.

Strong diurnal variation in oxidant concentrations were recorded between mountain and valley locations, with the highest concentration on mountains occurring at night and in the valley during the day. The reduction of the concentration in the valleys during the night may be due in part to oxidant reduction at the surface. A good portion of the oxidant may also be displaced to higher altitudes at night by cool air draining down mountain slopes.

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1964. Eastern white pine, a tool to detect air pollution. South. Lumberman 209(2609): 164, 166.

Clonal lines of eastern white pine are being developed for use as biological indicators of specific types of air pollutants. Use of these clones permits the detection of low levels of air pollution, determination of relative concentrations involved, and identification of specific pollutants.

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1965. Breaking dormancy in eastern white pine by cold and light. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-43, 3 pp.

Eight weeks' exposure to a temperature of 40° F. ± 2° and 9 hours of light per day satisfied the cold and light requirements of dormant eastern white pine seedlings, and growth was resumed in the greenhouse following treatment.

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1967. An exposure chamber for forestry air pollution studies. (Abstr.) Phytopathology 57: 804.

A lean-to greenhouse with a volume of 300 $ft.^3$ is being used to expose potted trees as tall as 6 ft. to phytotoxicants. Desired temperature is maintained by recirculating air through an air conditioner and electric strip heaters. Pneumatic mist nozzles and steam are used to keep relative humidity at specified levels. Because the chamber is largely glass, sunlight is used for illumination. Phytotoxicants, introduced into the chamber through a small tube leading into the air duct system, are monitored with automatic analyzers. Ozone concentrations from 0.0 to 1.0 p.p.m., and SO_2 concentrations from 0.0 to 5.0 p.p.m., can be maintained by manual adjustment of flowmeters. Temperature control can be maintained at ± 1.5° F., and humidity at ± 3 percent. Humidities up to 100 percent are possible at temperatures at or below 70° F.; above 70° F. somewhat lower humidities must be used. This chamber differs from similar ones in that it provides better control of a wide range of temperatures and humidities, independent of outside conditions.

——— **and Heggestad, H. E.**

1968. Air pollution detectives. U. S. Dep. Agr. Yearbook 1968: 142-146.

Damage to crops by air pollution costs more than $500 million annually in the United States. Many plants—including weeds, truck crops, and timber—help combat costly air pollution, even though they sustain repeated damage. The plants are used to detect the presence of and identify airborne pollutants, and to determine the distribution of toxicants and level of pollution. This article discusses the bio-indicator aspects of plants, the gases that injure them, and the injury symptoms. Plants resistant to and susceptible to each gas are listed.

Berry, C. R., and Hepting, G. H.

1964. Injury to eastern white pine by unidentified atmospheric constituents. Forest Sci. 10: 2-13.

A general decline of *Pinus strobus* L. found in the Kingston-Oak Ridge area of Tennessee and in other industrial areas was caused by an atmospheric agent. Trees differed greatly in susceptibility to the disease, and grafts made on healthy trees with both resistant and healthy scion material remained in their original condition when left in the affected area. Sulfur dioxide and fluorine are regarded as possible causes of this injury.

Bethune, J. E.

1964. Phosphate helps grow timber. Fla. Cattleman & Livestock J. 28 (8): 32.

After 3 years South Florida slash pines planted on phosphate-treated plots were 23 percent taller than trees on unfertilized plots. Pine foliage phosphorus levels were even higher than when the seedlings were lifted from the nursery. Wildfire hazard was practically eliminated by grazing on plots treated both by chopping and rock phosphate.

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1966. Performance of two slash pine varieties planted in south Florida. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-24, 9 pp.

Compares survival, growth, and other characteristics of planted South Florida slash pine (*Pinus elliottii* var. *densa* Little & Dorman) and the typical slash pine variety (*Pinus elliottii* var. *elliottii* Engelm.) through age 9. South Florida slash pine is more resistant to most pests and to fire, and suffers relatively less growth loss following cattle damage. The typical variety survives better, grows faster during the first years after planting, and has more resistance to wind damage.

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1967. Cost effectiveness budgeting: implications for forestry research. Soc. Amer. Forest. Proc. 1966: 136-138.

Cost effectiveness analysis provides the analytical base for the Planning-Programing-Budgeting System newly adopted by most agencies of the United States Government. It is a rational approach to investment decision-making, underlaid by a foundation of mathematical and statistical concepts. Once cost effectiveness budgeting procedures are fully implemented, funds for all phases of forestry will be allocated only to the extent their expenditure can be demonstrated to return greater net benefits than investments in competing alternatives. Well-conceived, competently executed research is usually the only reliable source of treatment-response schedules, the basic data for the analyses. Properly formulated, cost effectiveness analyses can help transform research accomplishment into improved forest management procedures.

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1967. Forest operations analysis: new approach to management planning. Forest Farmer 26(5): 16, 22, 23.

Operations analysis is the basis for a new computer-oriented approach to management planning. This paper contains a discussion of the areas in which an operation analysis approach should prove of value to forest management and a brief explanation of how the technique works. The success of this technique depends on the availability of reliable data on how the forest responds to management. The operations analysis approach to management planning should become an important tool for obtaining maximum returns from managed woodlands.

Bethune, J. E.
1967. Manipulation of stand density in planted southern pines for maximum pulp yield. Tech. Assoc. Pulp & Pap. Ind., Fourth Forest Biol. Conf. Proc. 1967: 111-119.

Control of stand density is the most powerful means available to the forester for implementing decisions about quantity, quality, and timing of wood flow. Decisions concerning levels of growing stock for optimum yields must be based on reliable growth data for varying species, ages, sites, stand densities, and management regimes. The development of growth and yield tables for planted southern pines and the recent evolution of means for predicting stand structure provide a means for rational planning. This paper discusses how growth and yield information presently available can assist the southern industrial forester in management planning and how information on pulp yield and on silviculture-pulp yield interactions might be used to design forest management systems for optimum yields.

——— and Langdon, O. G.
1966. Seed source, seed size, and seedling grade relationships in South Florida slash pine. J. Forest. 64: 120-124.

Differences in survival, growth, and pest resistance of planted South Florida slash pine (*Pinus elliottii* Engelm. var. *densa* Little and Dorman) from two sources, two seed sizes, and three seedling grades are reported. Findings indicate the possibility of improvement in survival and early growth of planted South Florida slash pine by careful selection of seed source and seedling grade.

lackmarr, W. H., and Flanner, W. B.
1968. Seasonal and diurnal variation in moisture content of six species of pocosin shrubs. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-33, 11 pp.

Seasonal variation in the moisture content of six species of pocosin shrubs was observed over a 10-month period during 1965. The variation in the moisture content of the foliage and stems is compared with the average moisture content of the whole plant.

Moisture contents of both stems and foliage reached their lowest levels during the fall and early spring. The moisture content of most species increased rapidly throughout May, reaching a maximum during the first 2 weeks of June. The initiation of new foliage occurred at about the same time that the average moisture content of the whole plant began its rapid spring buildup.

Diurnal variation in the moisture content of the foliage of four shrub species was observed over a 36-hour period during June 21 and 22, 1965.

The moisture content of newly developed foliage exhibited noticeable diurnal fluctuation. Maximum moisture contents occurred between 2 and 6 a.m. Minimum moisture contents occurred between 2 and 6 p.m.

ois, P. J.
1967. Building a wood-disk patio? Treat it right! Amer. Forests 73(4): 32-33, 46. Also, with title How to make wood rounds last longer, in Flower & Gard. 11(11): 34, 46-47.

A method of constructing a wood-disk patio is described and illustrated. Emphasis is placed on proper preservative treatment of the wood disks with detailed directions on the use of two different treatments. Maintenance and cost of materials are also presented.

Bois, P. J.

1968. Weight of sawdust from several Southern Appalachian wood species. Forest Prod. J. 18(10): 52-54.

The weight of sawdust per cubic foot at three levels of compaction was determined for several species of the Southern Appalachians. At the two lower levels of compaction, the relationship of sawdust weight per unit of volume is linear with changes in moisture content. It becomes curvilinear at the highest level of compaction. Methods of calculating sawdust weight per unit volume at any moisture content or level of compaction are described.

——— **and Eslyn, W. E.**

1966. Deterioration rates of willow and cottonwood during storage in Georgia. Forest Prod. J. 16(11): 17-22.

Willow and cottonwood roundwood was stored in two commercial type piles for 8, 17, and 48 weeks. Samples were removed for specific gravity and moisture content determinations and bolts were examined for decay organisms. Pulp fiber classifications were made and freeness values were determined after each storage period. One pile was on a low damp site and produced greater decreases in specific gravity than the wood in the other pile stored on a higher and drier site.

Boyer, J. S., and Knipling, E. B.

1965. Isopiestic technique for measuring leaf water potentials with a thermocouple psychrometer. Nat. Acad. Sci. Proc. 54: 1044-1051.

New technique for determining rate of vapor flux between thermocouple and leaf which is free of error caused by leaf resistance. The method can be used to measure leaf resistance directly and gives more accurate measurements of water potential than other methods.

Bramlett, D. L.

1965. Shortleaf pine seed production in the Piedmont. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-38, 4 pp.

The 10-year records of annual shortleaf pine seedfall throughout the southeastern Piedmont have shown that three good seed years occurred. In the Georgia Piedmont, seed crops were more frequent than in the northern portions. The data support the theory that climate as well as the physical soil-site environment influence seed production of trees. Destructive agents, by reducing a good flower crop to a poor seed crop, can obscure the weather effects.

——— **and Hutchinson, J. G.**

1964. Estimating sound seed per cone in shortleaf pine. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-18, 2 pp.

A prediction equation was derived, $Y = 2.365 + 4.836X$, where Y = number of sound seed per cone and X = number of sound embryos exposed by slicing the cone lengthwise in half.

——— **and Hutchinson, J. G.**

1965. Pine sawfly larvae destroy shortleaf pine strobili in Virginia. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-42, 3 pp.

During the spring of 1963 a survey of shortleaf pine female flowers revealed that 9.6 percent of the flowers were killed by pine sawfly larvae. The following spring, mortality from sawfly larvae was 3.8 percent. In 1964, the percentage of flower mortality attributable to the sawfly was low. Male strobili were also damaged by sawfly larvae.

rendemuehl, R. H.

1968. Research progress in the use of fertilizers to increase pine growth on the Florida Sandhills, pp. 191-196. *In* Forest fertilization theory and practice symposium 1967. Tenn. Val. Authority, Muscle Shoals, Ala.

Fertilization to increase pine growth on the well-drained to excessively drained soils of the Florida Sandhills is still in the experimental stage. The existing scrub oak and wiregrass cover should be eliminated to grow pines on these sites but with a minimum of soil disturbance. Sand (*Pinus clausa* (Chapm.) Vasey), longleaf (*P. palustris* Mill.), and slash (*P. elliottii* var. *elliottii* Engelm.) pines are the species best adapted to these sites. Phosphorus has been found to be the element in shortest supply for pine growth on Sandhills soils. Information is accumulating which indicates that on well-drained soils phosphorus placement is critical if trees are to receive full benefit from applications of the common forms of this fertilizer. Phosphorus applied in combination with nitrogen in a 1:1 ratio has produced the greatest growth response.

render, E. V.

1965. Growth and yield of planted loblolly pine, pp. 213-220. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Sums up available information on influence of spacing and site quality on growth and yield of young loblolly pine plantations, and deals with establishment and investment costs, merchantable volume production, and dollar returns.

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1965. Harvesting loblolly pine, pp. 119-124. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Considers the suitability of various harvest and regeneration methods in loblolly pine plantations for different owner product objectives.

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1965. Initial spacing in loblolly pine, pp. 40-47. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Discusses factors which should influence initial spacing in loblolly pine plantations, such as species characteristics, site quality of the land, and desired product objectives.

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1965. Thinning loblolly pine, pp. 99-110. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Discusses the use of thinning to determine future growth of loblolly pine plantations.

Brender, E. V., and Cooper, R. W.

1968. Prescribed burning in Georgia's Piedmont loblolly pine stands. J. Forest. 66: 31-36.

Summer prescribed fires were successful in killing back understory hardwoods and aiding the establishment of free-growing loblolly pine seedlings in Georgia's lower Piedmont. No significant differences in the top-kill of hardwood stems were found between backfires and strip head fires; the kill from summer fires, however, was significantly greater than kill from winter fires. New regeneration following summer fires was twice as plentiful as on unburned tracts. Although results indicated no significant differences between burning techniques, strip head fires were less costly than backfires and generally less subject to wind fluctuations in hilly terrain. Wind speeds of at least 1 mile per hour within the stands were essential for proper fire movement. Optimum moisture condition for fine fuel was between 10 and 20 percent, with relative humidity from 25 to 50 percent.

———— **and Moyer, E. L.**

1965. Further progress in the control of kudzu. Down to Earth 29(4): 16-17.

Tordon (4-amino-3,5,6-trichloropicolinic acid) can be used to eradicate kudzu, but it also killed established loblolly pines. Seedlings planted 6 months after Tordon application grew well for at least 2 years.

———— **and Romancier, R. M.**

1965. Glaze damage to loblolly and slash pine, pp. 156-159. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

In areas subject to frequent glaze storms, loblolly pine should be planted rather than slash pine. To minimize glaze damage, spacing closer than 6 by 8 feet should not be used; thinnings should be made early and frequently; not more than one-third of the basal area should be removed at a time. Row thinning or thinning from above should be avoided.

Broadfoot, W. M., and Ike, A. F.

1967. Fertilizing southern hardwoods. Ala. Forest Prod. Dir. 10(7): 41, 43, 45.

Fertilizer research work in the mid-south and southeast has shown that: (1) sycamore and yellow-poplar seedlings respond to N fertilization the first growing season on moist Piedmont sites, (2) fertilization response of young cottonwood on alluvial soils is slight and varies with soil type, (3) the height and diameter growth of 20-year-old oak and sweetgum in a natural stand growing on Sharkey clay was stimulated with N alone and with a complete (NPK) fertilizer formulation.

Brown, C. L., and McAlpine, R. G.

1964. Propagation of sweetgum from root cuttings. Ga. Forest Res. Counc. Res. Pap. 24, 5 pp.

Sweetgum can be successfully propagated from root cuttings. Cuttings taken in mid-June from roots of 3-year-old seedlings and 20-year-old trees were placed upright in a medium composed of a 1-to-1 mixture of sand and decomposed sawdust. By October a high percentage of cuttings had produced both buds and roots. Cuttings from seedlings not only produced more buds from each cutting, earlier, but also produced faster growing shoots than cuttings from the older trees. Success in propagation was over 90 percent for seedling material and ranged from 20 to 93 percent for cuttings from 20-year-old trees. A Kinetin-lanolin paste applied to the upper surface of several rows of cuttings apparently did not stimulate bud formation.

Brown, C. L., McAlpine, R. G., and Kormanik, P. P.

1967. Apical dominance and form in woody plants: a reappraisal. Amer. J. Bot. 54: 153-162.

The form of woody plants is commonly interpreted in terms of apical dominance. Trees with the decurrent or deliquescent branching habit are said to have weak apical dominance, whereas excurrent branching is associated with strong apical dominance. A close examination of many decurrent species such as the oaks, hickories, and maples reveals that almost all of the lateral buds on the current year's twigs are completely inhibited. This complete inhibition of lateral buds by definition and common usage of the term is an expression of strong apical dominance. In trees possessing the excurrent branching habit, such as most conifers and some angiosperms, many of the lateral buds on the current year's twigs elongate to varying degrees. This is usually interpreted as an expression of weak apical dominance. The relationship between bud inhibition and form in woody perennials is much more complex than bud inhibition in herbaceous plants because of the time sequence in the formation and release of lateral buds. For example, it is only after a period of rest or dormancy in the decurrent forms that one or more of the uppermost lateral buds are released, and these may outgrow the currently elongating terminal shoot resulting in forking. Conversely, in the excurrent forms, it seems that the initial expression of weak apical dominance enables the terminal leader to outgrow the currently elongating lateral branches so that it exerts complete control over their subsquent growth and development in later years. An examination of the levels of diffusible auxin at different points along the twigs of excurrent and decurrent species indicates that the balance of growth factors at any given locus, and not the absolute quantity of auxin, exerts primary control over bud inhibition and shoot elongation.

rown, R. A., and Rowan, S. J.

1967. Sodium arsenite: a possible eradicant of fusiform rust infections. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-75, 3 pp.

Applications of sodium arsenite were made to fusiform rust stem infections on slash and loblolly pines to test the effectiveness of this chemical in eradicating infections. Preliminary data are not conclusive, but sodium arsenite may be of value in eradicating fusiform rust infections on high value plantings.

ryan, W. C.

1965. Testing shortleaf pine seedlings for resistance to infection by *Phytophthora cinnamomi.* Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-50, 4 pp.

Trees of cone-bearing age originating from grafted stock in a breeding area at Athens, Ga., were carefully control-pollinated, utilizing as pollen sources all clones represented in the orchard. Progeny from these pollinations were grown aseptically and subjected to zoospores of *Phytophthora cinnamomi* in test tubes. Progeny of several cross pollinations survived, but the progeny of the crosses readily succumbed. These tests indicate that the progeny of certain parent trees possess a high resistance to *P. cinnamomi.*

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1966. Loblolly pine a wise choice on littleleaf sites. South. Lumberman 213(2656): 174-175.

Observations in one plantation each of loblolly and shortleaf pine established 25 years ago on adjoining littleleaf sites in South Carolina, and thinned at the same time in 1960, show differences in susceptibility between the two species to littleleaf disease. Trees in the loblolly stand are now healthy and growing vigorously, while the shortleaf stand is breaking up with many trees dead and dying.

Buchanan, T. S.

1965. World situation with regard to forest diseases. *In* FAO/IUFRO symposium on internationally dangerous forest diseases and insects. Unasylva 19(3): 107-112.

Discusses forest disease losses as a worldwide problem; identifies eight ways in which tree diseases may cause direct losses in forest productivity and a ninth, indirect, source of loss; and shows that it is essential to measure the impact of forest tree diseases for (1) procurement of more accurate net forest inventories, (2) guidance of forest disease control programs, and (3) direction to forest disease research efforts.

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1967. 49. Diplodia twig blight of pine. *Diplodia pinea* (Desm.) Kickx (Syn: *Sphaeropsis ellisii* Sacc.), pp. 189-191. *In* A. G. Davidson and R. M. Prentice [ed.], Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. Dep. Forest. & Rural Develop., Canada, Pub. 1180.

Contribution on forest pest problems by the Working Group on Forest Insects and Diseases, North American Forestry Commission, FAO.

Burns, R. M.

1968. Sand pine: Florida's much maligned pioneer. South. Lumberman 217(2704): 179-181.

Sand pine, a tree native to Florida and coastal Alabama, has demonstrated an adaptability to the sandhills for exceeding the expectations implied by the name "scrub pine." In 13-year-old comparative plantings on deep, well-drained sandy soils it outgrows slash and longleaf pines by more than a foot per year. Despite a slightly lower cordwood price, sand pine holds promise of becoming the principal pulpwood species for reclamation of scrub oak and wiregrass dominated sandhills.

Byram, G. M.

1966. Scaling laws for modeling mass fires. Pyrodynamics 4(3): 271-284.

Scaling laws are developed for the stationary area or "mass" fire by the methods of dimensional analysis. In general, geometric similarity is determined by two dimensionless groups—a buoyancy number and a Froude number. Additional groups from the dimensional analyses give the scaling laws for variables such as lengths, times, accelerations, and temperatures.

——— **Clements, H. B., Bishop, M. E., and Nelson, R. M., Jr.**

1966. Final report project fire model — an experimental study of model fires. USDA Forest Serv. Southeast. Forest Exp. Sta., 51 pp.

A series of experimental laboratory fires was burned to obtain a better understanding of the mechanisms of fire spread and the significance of some of the variables involved. Fires were burned in pools of liquid ethanol and fabricated wooden cribs. Results from wind fires on flat surfaces and slope fires in still air indicate that two of the basic spread parameters, fuel bed burnout time and unit area burning rate, may be nearly independent of wind speed and slope angle. Other experiments on flame characteristics, weight distribution across the burning zone, and effect of moisture content on rate of spread are also discussed.

Cade, S. C., and Heikkenen, H. J.

1965. Control of pine tip moths on loblolly pine with systemic insecticides. Ga. Forest Res. Counc. Res. Pap. 32, 4 pp.

The ability of several systemic insecticides (Di-syston, Shell-1836, Thimet, Tetram, and Menagon) to control the pine tip moth in loblolly pine seedlings, outplanted trees, and seed orchard trees was tested. Thimet and Di-syston appear to be the most promising.

Campbell, R. A.

1964. Forest Service log grades for southern pine. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-11, 17 pp.

Specifications of a southern pine log grade system adopted by the U.S. Forest Service after 30 years of research. Green and dry lumber yields are shown by log grade and species group.

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1964. Southern yellow pine log grades. South. Lumberman 209(2600): 28-30.

A summary of the historical background of southern pine log grade development within the Forest Service. Lumber yields by log grade, size, and species group are shown, and the need for separate yields tables for loblolly-shortleaf and slash-longleaf is explained. Log grading specifications, grading procedures, and examples of uses and users of these log grades are presented.

Campbell, W. A.

1964. Forest Service laboratory in operation. Univ. Ga. Sch. Forest., Cypress Knee, pp. 58, 64.

The Forestry Sciences Laboratory which was completed on the University of Georgia campus in 1963 is described, as well as its place in the Southeastern Forest Experiment Station organization, planned personnel, and its program.

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1965. Reducing losses from diseases in pine plantations, pp. 146-155. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Emphasizes the control of brown spot, fusiform rust, and annosus root rot in plantations, and the factors influencing disease expression.

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1967. 14. *Phytophthora* spp. *Phytophthora* spp., particularly *P. cactorum* (Lebert and Cohn) Schroet., *P. cinnamomi* Rands, and *P. lateralis* Tucker and Milbrath, pp. 57-60. *In* A. G. Davidson and R. M. Prentice [ed.], Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. Dep. Forest. & Rural Develop., Canada, Pub. 1180.

Contribution on forest pest problems by the Working Group on Forest Insects and Diseases, North American Forestry Commission, FAO.

——— **and Gallegly, M. E.**

1965. *Phytophthora heveae* from eastern Tennessee and western North Carolina. U. S. Dep. Agr. Plant Dis. Rep. 49: 233-234.

Assays of soil samples for *Phytophthora* species from old-growth hardwood stands revealed the presence of *P. heveae* at two locations in eastern Tennessee and western North Carolina. This fungus, originally described from heveae rubber trees in Malaya, had not been reported from North America.

——— **and Hendrix, F. F., Jr.**

1966. *Pythium* and *Phytophthora* spp. in forest soils of the Southeast. (Abstr.) Phytopathology 56: 873.

Eleven identifiable *Pythium* and *Phytophthora* species were found in forest soils in order of frequency of isolation as follows: *Pythium sylvaticum, Phytophthora cinnamomi, Pythium irregulare, P. vexans, P. paroecandrum, P. rostratum, Phytophthora cactorum, Pythium splendens, P. acanthicum, P. spinosum,* and *P. torulosum. Pythium* propagules per gram of soil varied from 0-185.

Campbell, W. A., and Hendrix, F. F., Jr.

1967. A new heterothallic *Pythium* from Southern United States. Mycologia 59: 274-278.

Most isolates of a *Pythium* sp. common to forest and agricultural soils of Southern United States formed only sporangia on hempseed agar medium. Paired matings on the same medium demonstrated the existence of plus and minus strains that produced oospores in abundance when the hyphae of compatible strains made contact. A few isolates were homothallic. On the basis of the heterothallic reaction and morphology of the antheridia, the fungus has been named *Pythium sylvaticum.*

——— **and Hendrix, F. F., Jr.**

1967. *Pythium* and *Phytophthora* populations in southern forest tree nurseries. (Abstr.) Phytopathology 57: 457. Also in (Abstr.) Assoc. South. Agr. Workers Proc. 1967: 287.

During the period May to September 1966, 70 composite soil samples from 16 nurseries in Florida, Georgia, Louisiana, North Carolina, and South Carolina were assayed for *Pythium* and *Phytophthora* spp. by Hendrix and Kuhlman's modified Kerr's *Pythium* medium. Propagules/g. soil varied from 0 to more than 100. Fourteen samples yielded no propagules/g. soil, 23 yielded 0.1-10/g., 8 yielded 10-20/g., 4 yielded 20-30/g., 4 yielded 30-40/g., 7 yielded 40-50/g., and 10 yielded more than 50/g. Fumigation influenced populations; beds recently treated with methyl bromide had low populations. Isolates referable to the *Pythium debaryanum-P. irregulare* complex were obtained from samples under pine seedlings in 14 nurseries, *P. sylvaticum* in 7, *P. spinosum* in 4, *P. splendens* in 1, *P. helicoides* in 1, and *Pythium* spp. in 2. *Phytophthora cinnamomi* was present in one nursery growing Fraser fir. Large *Pythium* populations were associated with stunting and yellowing in some nurseries. In the greenhouse, *P. irregulare* was strongly pathogenic, reducing the total emerged seedlings in 2 months by 58% for shortleaf pine, 32% for loblolly, and 12% for slash. *Pythium sylvaticum* was only slightly parasitic. Slash pine showed the greatest resistance to several *Pythium* spp.; loblolly was next and shortleaf pine was the most susceptible.

——— **and Hendrix, F. F., Jr.**

1967. *Pythium* and *Phytophthora* species in forest soils in the southeastern United States. U. S. Dep. Agr. Plant Dis. Rep. 51: 929-932.

Forty-three soil samples from mountain hardwoods and coniferous stands in northern Georgia, eastern Tennessee, and western North Carolina, and 31 samples from the Piedmont and coastal plain of Georgia, South Carolina, and North Carolina were assayed for *Pythium* and *Phytophthora* species by the apple technique and by a modified Kerr's agar medium. Fungi recovered, in order of frequency of isolation, were: *Pythium sylvaticum, Phytophthora cinnamomi, Pythium irregulare, P. vexans, P. paroecandrum, P. rostratum, Phytophthora cactorum, Pythium splendens, P. acanthicum, P. spinosum,* and *P. torulosum.* Phytophthora and Pythium propagules per gram of soil varied from 0 to 185 per sample. From a total of 101 samples, 18 gave 0 propagules, 35 gave 1 to 10, 18 gave 10-30, 7 gave 30-50, 11 gave 50-70, and 12 gave 70 or more.

Carpenter, B. E., Jr., and Schroeder, J. G.

1968. Combined effects of drying, surfacing, and trimming on grade and volume of southern pine lumber. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Note SE-93, 3 pp.

This paper shows how the grade and volume of 1-inch and dimension lumber changed due to drying, surfacing, and remanufacturing during a southern pine lumber yield study.

Chappelle, D. E., and Nelson, T. C.

1964. Estimation of optimal stocking levels and rotation ages of loblolly pine. Forest Sci. 10: 471-502.

Models are developed for estimating optimal growing stock levels and rotation ages for loblolly pine. Under a profit maximization goal, they provide for varying stumpage prices, stand ages, site indexes, stocking levels, alternative rates of return, and regeneration costs for two single-product objectives. Quality differential as expressed in stumpage prices is recognized. A system is also provided for determining optimal stocking levels at the same marginal rate of return as that selected for determining optimal rotation age. Using a loblolly pine growth study in the Southeast for the biological data, solutions of stocking levels at various alternative rates of return indicate that stocking standards for profit maximization are much less than levels which optimize physical production. Rotation age solutions indicated that rotations lengthened as the alternative rate of return is reduced, as the site index increased, and as a quality differential is introduced.

Clark, E. W.

1965. An artificial diet for the southern pine beetle and other bark beetles. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-45, 3 pp.

Two variations of an artificial diet are described, one containing inner pine bark and the other pure powdered cellulose. Methods for preparing the diet, installing eggs or larvae, and subsequent rearing are also presented.

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1965. A simple rearing technique for obtaining eggs or young larvae of the southern pine beetle. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-44, 2 pp.

Six to 10 pairs of beetles are confined to the end of a 14-inch pine bolt in a chamber of polyethylene sheeting and heavy paper. The bolt is kept upright in a rearing room maintained at diurnal temperatures of 82° and 72° F. After 6 to 12 days, the galleries are carefully exposed and the eggs or larvae removed.

——— **and Osgood, E. A., Jr.**

1964. An emergence container for recovering southern pine beetles from infested bolts. J. Econ. Entomol. 57: 783-784.

A container for collecting emerging beetles and the accompanying technique are described. The container consists of a trash can to which has been added a funnel and mason jar at the base. The beetles, emerging from infested material, gather in the mason jar because of their photopositive reaction.

——— **and Osgood, E. A., Jr.**

1964. Mass rearing the southern pine beetle and the coarse writing engraver. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-30, 4 pp.

Large numbers of these scolytid beetles are continuously reared on short pine bolts in modified trash cans which are also used for emergence collectors. The rearing technique and the emergence container are described.

——— **and Osgood, E. A., Jr.**

1964. A simple laboratory technique for rearing *Ips calligraphus*. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-31, 3 pp.

Ips calligraphus is reared continuously on short 3- to 5-day-old pine bolts. These pine bolts are kept in 12- by 12- by 18-inch screen cages and maintained between 22° and 30° C. and 45- to 60-percent relative humidity. The construction of the cage and small emergence collector is also described.

Clark, E. W., and Richmond, C. A.

1964. Changes in weight of abraded and unabraded larval pink bollworm under submersion and desiccation. J. Econ. Entomol. 57: 14-16.

In general, abrasion caused greater changes in water content and increased mortality. It took twice as long for the weight change in diapause larvae to equal the change in nondiapause larvae.

Clements, R. W.

1964. Four years of gum production with a total face height of only 45 inches. AT-FA J. 26(4): 5-8. Also, with title Back cupping produces more gum and reduces total face height, in Nav. Stores Rev. 73(11): 8-9, 17.

A method was needed for working trees 4 years with face heights less than 54 inches. Olustee developed and tested the technique of working intensively 2 years on front face, then 2 years on back face. Yields exceeded standard work of 4 years on front face by 12 percent on planted slash and 22 percent on natural longleaf. Final face heights were only 45 inches. Now 4 years of work are possible on limited face-height leases, resulting in more income to timber owner and gum producer. A better quality of workmanship is possible because the chipper has no pulling work or hazardous treating of high faces, and gum waste is kept at a minimum on these low faces.

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1964. Noncorrosive chemical produces good gum yields in slash pine. AT-FA J. 27(2): 14-17. Also in Nav. Stores Rev. 74(8): 4-5, 7.

Treatment of slash pine with a 2-percent solution of 2,4-D gives good gum yields, provides safer working conditions for chipping laborers, eliminates the acid corrosion problem, increases the life of galvanized iron cups and tins, and produces higher grades of gum.

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1965. The gum naval stores industry must become more scientific. AT-FA J. 27(10): 17.

The need for improved or new techniques and methods.

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1965. Sulfuric acid paste shows promise as means of reducing production costs. AT-FA J. 27(9): 3-4. Also in Nav. Stores Rev. 75(3): 7, 11.

Sixty percent sulfuric acid paste shows promise for prolonging gum flow for 3 and 4 weeks. Eleven triweekly streaks per year, over a 2-year period, produced as much gum as 16 streaks with standard treatment. Eight monthly streaks produced 88 percent of the volume obtained from 16 biweekly streaks. Use of the streak-a-month method could result in reduced production costs due to a saving in the number of annual visits to each worked tree.

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1966. When and how to use acid paste. AT-FA J. 28(6): 6-7.

Using the monthly paste method, one laborer can chip and treat 78 percent more faces and produce 52 percent more gum per month than from standard methods currently in use.

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1967. Acid paste method highly successful in commercial operations. Nav. Stores Rev. 77(6): 4, 6, 9. Also in AT-FA J. 30(1): 4, 6-7.

In a 2-year evaluation of the commercial use of acid paste to prolong gum flow from slash and longleaf pines, 22 paste streaks produced as much gum as 32 standard acid-spray streaks. By using paste at 21-day chipping intervals, each chipping laborer increased his gum production per streak by 46 percent.

Clements, R. W.

1968. Willingness to change—key to survival for the gum naval stores industry. Nav. Stores Rev. 78(9): 4-5.

The author cites the need and basic reasons for the gum naval stores industry to change from its archaic system of production to modern concepts in the extraction of gum from southern pines. Economic pressure from other products and a diminishing supply of labor demand that efficiency in operation and reduction of costs receive serious consideration by the gum producer for profitable production in the future.

——— and Cross, J. K.

1964. Back cupping produces more gum than front faces in Mississippi test. Nav. Stores Rev. 74(3): 4, 6-7. Also in AT-FA J. 26(9): 10-12.

If properly used, the front and back face method described will substantially increase the income for both gum production and timber leasing. Another 2 years of work is provided on the same tree without impairing stumpage value of the tree for other products.

——— and Harrington, T. A.

1965. Gum naval stores from plantations, pp. 199-210. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Pine gum and timber are compatible products from good management of forest plantations in the Southeast. With careful planning and capable supervision, the production of gum and timber makes a more profitable operation than the production of either product alone.

Clutter, J. L., and Bennett, F. A.

1965. Diameter distributions in old-field slash pine plantations. Ga. Forest Res. Counc. Rep. 13, 9 pp.

Method of predicting diameter distributions in old-field slash pine plantations by age, site, and density schedules, and accuracy tests of the predicted values in comparison with actual distributions. With such data it is possible to: (1) forecast the number of merchantable stems per acre for either pulpwood or sawtimber; (2) predict the number of trees per acre large enough for naval production; (3) determine optimum spacings for multiple-product combinations; and (4) evaluate harvesting costs.

Collins, A. B. III

1964. Longleaf pine seed source planting in Georgia—tenth-year results. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-19, 3 pp.

Six seed sources of longleaf pine at age 10 show height growth correlated with latitude or temperature. The greatest difference in height between sources, 4.7 feet, was the difference between the coastal plain Alabama and the Piedmont Alabama sources. Since only 0.2 foot separated the Georgia and Texas sources, longitude appears to have little effect on height growth. An average survival of 80 percent for the entire study and average height of 25 feet at age 10 indicate species diversification is practical.

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1964. Tenth-year results of loblolly pine seed source planting in Georgia. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-20, 4 pp.

Growth and development of nine seed sources of loblolly pine ranging from Maryland to Texas are compared. Height growth increases as the source moves south and east. Fusiform infection also increases as the source moves south and east, going from a low of 5 percent for the Texas source to 51 percent for the Georgia source. Infection of the Maryland source amounted to only 12 percent.

Collins, A. B. III

1965. Topwood volume tables for old-field slash pine plantations. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-51, 3 pp.

Topwood volume tables to supplement already published board-foot volume tables. Total and merchantable topwood volumes to 4- and 2-inch minimum top diameter limits were measured, and linear regression techniques were used to develop volume estimates as functions of total height and d.b.h. Estimates are given for topwood yield per thousand board feet.

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1967. Density and height growth in natural slash pine. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-27, 8 pp.

Three thinning treatments were applied to plots of 3-year-old natural slash pine with up to 50,000 seedlings per acre. Measurements 14 years later prove height growth is reduced significantly in dense stands. For short pulpwood rotation, early thinning is imperative. It will also increase height and merchantable volume for later harvests. In dense, unthinned, natural stands, dominant height is not a true indicator of productive potential for a managed stand on the same site.

Colquitt, J. W., and Johansen, R. W.

1967. Developing foam with an aerial tanker. USDA Forest Serv. Fire Contr. Notes 28(1): 8, 11.

Foam was made when either protein-base or high-expansion foam solution was dropped from an aerial tanker, but considerable foam drift and dissipation was experienced in light winds.

Cookingham, R. A., and Ripley, T. H.

1964. Some observations on the response of an insular quail population to supplemental feeding. Bird-Banding 35(4): 266-267.

An insular quail population in Massachusetts showed little response to removal of supplemental feed provided in bucket feeders during the winter.

——— **and Ripley, T. H.**

1964. Vital characteristics of an insular bobwhite population. J. Wildlife Manage. 28: 855-857.

Thirteen wild bobwhites (*Colinus virginianus*), survivors from 17 birds trapped on Cape Cod and liberated on Great Island in West Yarmouth, Massachusetts, in 1954, increased to a fall population level of 94 birds within two breeding seasons. The annual overwintering population increased sharply the first 2 years, then leveled off and stabilized between 5 and 7 years. Summer gains showed a marked inverse relation to level of the overwintering population. Overwintering mortality apparently remained constant, regardless of population density. Postnesting survival may have been the factor most closely associated with change in population density. No specific findings for sex and age composition appeared related to characteristics peculiar to an expanding population.

Cooper, R. W.

1964. Prescribed burning research in the South. Va. Forests 19(3): 13, 26, 28.

The purposes and procedures of using prescribed fire, and the progress of the research program.

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1964. The role of chemical fire retardants in forest fire control. The Unit 102: 31-32.

A resumé of short-term and long-term firefighting chemicals used in combating forest fires.

ooper, R. W.

1965. The impact of current forest fire research. 4th Auburn Forest. Forum Proc. 1965: 15-19.

Forest fire research results should lead to fewer and smaller wildfires, and improved procedures for controlling the blowup. They should also provide the resource manager with the knowhow to make full use of prescription fires—in reducing hazards, manipulating stand composition, improving regeneration, or as a remedy for disease problems.

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1965. Wind movement in pine stands. Ga. Forest Res. Counc. Res. Pap. 33, 4 pp.

Wind movement 4 feet above ground was measured in pine stands of varying densities and heights. The relationship between within-stand wind movement and that in the open was established and conversion values prepared. Wind speed in the forest was found directly related to stand height and inversely related to basal area. Measurements of these stand characteristics are needed if conversion figures are to be used.

———

1966. New developments in forest fire suppression. (Abstr.) Assoc. South. Agr. Workers Proc. 1966: 184.

Significant developments include new chemical firefighting materials, high-velocity fans for dispersing retardant solutions, ground tankers with special pumping equipment, aerial tankers that can operate from land as well as large bodies of water, sand casters that build firebreaks and throw large volumes of soil, new explosives for line construction and firing operations, and an infrared scanner that can detect and map fires at night or during periods of intense smoke. Suppression burning is finding greater application as a means of controlling wildfires.

———

1967. Training through prescribed fire seminars. Sixth Annu. Tall Timbers Fire Ecol. Conf. Proc. 1967: 128-133.

In recent years, the Forest Service has embarked on a program of Research Seminars designed to carry latest research findings to practitioners, teachers, and consultants. Our most recent and probably most timely seminar, in light of need and demand, was on Prescribed Fire. In cooperation with experienced prescribed burners from industry, state agencies, and other branches of the Forest Service, the three Forest Fire Laboratories organized and carried out this seminar in 1966. The program emcompassed all phases of a prescribed burning operation and permitted a free exchange of ideas and experiences between instructors and trainees alike. In addition, the participants were equipped with material so that they could train their own personnel in the wise use of prescribed fire. At the Macon seminars, the Fire Control Simulator was used for the practical exercises and proved highly successful.

———

1968. Developments in forest fire research and their application to forest fire control. Forest Farmer Manual 27(7): 8-10.

Recent developments in forest fire research are successfully reducing the damage and acreage loss from wildfires. Included among the more significant developments are infrared sensors for mapping fires from the air, improved firefighting chemicals and means of application, new control equipment such as the Michigan Sandcaster, improved remote ignition techniques for suppressing fires, recommended plantation layouts to be used in conjunction with prescribed fires for protection against wildfires, and progress in fire-weather prediction and interpretation.

Cooper, R. W.

1968. Research developments at the Southern Forest Fire Laboratory. (Abstr.) Assoc. South. Agr. Workers Proc. 1968: 134.

In existence now for 8 years, the Southern Forest Fire Laboratory in Macon, Georgia, is responsible for a number of research developments that are successfully reducing the damage and acreage loss from wildfires. Included among the more significant developments are improved firefighting chemicals and means of application, new control equipment, improved remote ignition techniques for suppression fires, progress in fire-weather predictions and interpretation, and a standardized fire danger rating system. In addition, guidelines have been developed that permit the extension and wise use of prescribed fire as a tool of forest management.

——— **and Smith, A. D.**

1968. Simulating prescribed fires—a new training technique. USDA Forest Serv. Fire Contr. Notes 29(1): 11-13, 16.

Training personnel in the control and use of fire is not an easy task; classroom sessions generally fell short of their mark because they lacked the realism and authenticity that usually is achieved only through field experience.

In 1962, the Forest Service developed its first Fire Control Simulator to teach firefighters strategy and tactics. The effort has been most rewarding. By bringing fire into the classroom, we have been able to produce lifelike situations that have bolstered our training sessions considerably. The prescribed burner, like the fire control specialist before the day of the Simulator, had to learn his trade the hard way. Could simulation help in a training effort directed toward prescription fires as it did in control exercises? We thought it might.

At the Southern Forest Fire Laboratory, as part of the Forest Service conducted Research Seminars in Prescribed Fire, we used the Simulator for the important burning exercises, essential supplements to the classroom sessions. Weather was no problem—we created the environment as needed—and the enterprise met with complete success. Simulation proved to be an excellent method for quick, inexpensive, and realistic training in the use of prescribed fire.

Cost, N. D.

1966. Pulpwood prices in the Southeast, 1963-1965. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-65, 2 pp.

All-wood prices were $17.65 per cord for rough pine pulpwood and $14.35 per cord for hardwood. Chips were $6.65 and $5.55 per ton for pine and hardwoods, respectively.

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1968. Forest statistics for the Southern Coastal Plain of South Carolina, 1968. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Resource Bull. SE-12, 35 pp.

Since 1958, area of commercial forest land in the Southern Coastal Plain of South Carolina has increased by 5 percent and now totals almost 3.3 million acres, or 63 percent of the total land area. Volume of softwood timber, which had been decreasing before 1958, has increased by 29 percent. Hardwood volume continues to increase, and at a faster rate than between the two previous surveys. In 1967, growth exceeded removals by 46 percent with over 60 percent of the excess growth in pine.

ost, N. D.

1968. Southern pulpwood production, 1967. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Resource Bull. SE-11, 23 pp.

Pulpwood production in the South leveled off slightly in 1967 but still established another record high of 33,651,100 cords—63 percent of the Nation's total. Significant gains were noted in the use of residues, whereas roundwood production showed a slight decrease for the first time in 10 years. At the year's end, there were 92 mills in operation in the South with a total daily pulping capacity exceeding 70,000 tons; and eight new mills now under construction will boost the total daily capacity by 5,300 tons.

otrufo, Cosimo, and Berry, C. R.

1968. Some nutritional effects on sensitivity of eastern white pine to air pollution injury. (Abstr.) Plant Physiol. 43 (Suppl.): S-4.

Two experiments on the effects of air pollution on fertilized potted ramets of eastern white pine, *Pinus strobus* L., clones were carried out, one in the greenhouse and one in a field area in which sulfur dioxide was believed to be a major pollutant in the natural environment. The greenhouse-grown ramets were artificially exposed to SO_2 for 2 hours at 0.25 p.p.m. when the needles were 25-50 mm. long. In both experiments known susceptible and tolerant clones, in the greenhouse and in the field, were treated with a commercial soluble fertilizer of 28:19:17 formulation at concentrations of 0 to 2 grams per pot and 0 to 32 grams per pot, respectively. Both fertilizer treatments generally increased the tolerance of several susceptible clones to air pollution injury. This was most strikingly manifested through reduction of needle tipburn symptoms. In the field experiment, certain other symptoms, such as banding and mottling, were not alleviated by fertilizer application.

ushwa, C. T.

1968. Fire: a summary of literature in the United States from the mid-1920's to 1966. USDA Forest Serv. Southeast. Forest Exp. Sta., 117 pp.

This paper lists 823 references to literature concerning properties, uses, and effects of controlled and uncontrolled fire, from the mid-1920's to the present, published mainly in the United States. References were placed into 16 major topic categories. Several of the broad categories, such as forestry, were divided into subcategories to provide a list of references for specific topics.

——— **Brender, E. V., and Cooper, R. W.**

1966. The response of herbaceous vegetation to prescribed burning. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-53, 2 pp.

Prescribed burning in pine stands of the lower Piedmont may increase the number of quail food plants.

——— **and McGinnes, B. S.**

1964. Sampling procedures and estimates of year-round recreation use on 100 square miles of the George Washington National Forest. Twenty-Eighth N. Amer. Wildlife & Natur. Resources Conf. Trans. 1963: 457-465.

A 1-year, case-history sampling study of recreation use on a 100-square-mile unit of the George Washington National Forest indicated that, with no knowledge of optimum allocation of sampling effort, estimates of total use could be accurately made. Component uses in most cases were also predicted with low errors.

In this study a total of 700,000 man-hours of recreation use was examined in the light of area resources and recreation opportunities. Although the distribution of uses differed considerably from nationwide data reported by ORRRC, use was clearly related to forest resources and recreation opportunity in the area.

Cushwa, C. T., McGinnes, B. S., and Ripley, T. H.

1965. Forest recreation estimates and predictions in the North River area, George Washington National Forest, Virginia. Va. Agr. Exp. Sta. Bull. 558, 48 pp.

This study showed that a stratified random sampling plan (with no prior knowledge of how to optimize sampling effort) could be used to produce acceptable estimates of total and component recreational uses. Also, significant important relations were detected between users and uses which could provide a basis for decisions concerning present and future recreational management plus criteria for selecting management alternatives.

——— **Martin, R. E., and Miller, R. L.**

1968. The effects of fire on seed germination. J. Range Manage. 21: 250-254.

Fire is characteristically used in the pineywoods of the Southeast to produce repetitive abundant stands of native legumes. However, results are frequently erratic and unpredictable. Seed germination results following simulated fire conditions are presented. Results show dry heat ineffective in increasing germination, whereas moist heat greatly increased both germination rate and total germination of some species of seed.

——— **and Redd, J. B.**

1966. One prescribed burn and its effects on habitat of the Powhatan Game Management Area. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-61, 2 pp.

A hot prescribed fire on a recently clearcut 12-acre pine stand in the Virginia Piedmont increased the number of herbaceous wildlife food plants sevenfold and available seed per acre ninefold above production on an adjacent untreated control area.

Czuhai, Eugene, and Cushwa, C. T.

1968. A resumé of prescribed burnings on the Piedmont National Wildlife Refuge. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-86, 4 pp.

Information concerning the effects of prescribed burning on wildlife habitat in the Atlantic Piedmont is meager. Much information on this topic was in unpublished quarterly reports written by Piedmont Wildlife Refuge managers. This information has been summarized and presented chronologically.

DeBarr, G. L.

1967. Two new sucking insect pests of seed in southern pine seed orchards. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-78, 3 pp.

Two insects, a shield-back bug, *Tetyra bipunctata* (H. + S.) and a leaf-footed bug, *Leptoglossus corculus* (Say), were found feeding on the cones of longleaf pine, *Pinus palustris* Mill., and slash pine, *Pinus elliottii* Engelm., in north Florida. Preliminary observations on their biology and damage to seed are presented.

DeBell, D. S., and Auld, I. D.

1968. Robins and tupelo in low country swamp. S. C. Wildlife 15(1): 16.

Huge flocks of migrating robins arrive in a low-country swamp each fall and feed heavily upon the ripe fruits of swamp tupelo. Nearly half of the total seed crop passes through the birds' digestive tracts. This results in a wider, more uniform distribution than would otherwise occur with the heavy tupelo fruits. By favoring the very desirable swamp tupelo, foresters are ensuring an important source of food for migrating songbirds.

eBell, D. S., and Langdon, O. G.

1967. A look at an 11-year-old hardwood plantation. South. Lumberman 215(2680): 156-158.

Survival and growth of yellow-poplar, cherrybark, Shumard and swamp chestnut oaks, and loblolly pine in an 11-year-old plantation were examined. Because of intense competition from volunteer vegetation, the planted hardwoods were not dominating the site. Much of the competition consisted of rapidly growing, desirable species which tended to be more abundant and larger than the hardwood planted stock. Although planted loblolly pine had poor survival, its growth was excellent. It was concluded that planted hardwoods will need rather intensive care if they are to outgrow the vegetation which volunteers on these mixed bottomland sites.

——— **Langdon, O. G., and Stubbs, Jack**

1968. Reproducing mixed hardwoods by a seed-tree cutting in the Carolina Coastal Plain. South. Lumberman 217(2704): 121-123.

A seed-tree cut was made in an 85-acre stand of mixed bottomland hardwoods. Freshly cut stumps were sprayed with 2,4,5-T in oil to prevent sprouting. After logging was completed, residual woody vegetation taller than 4.5 feet was also treated wtih 2,4,5-T. Reproduction surveys revealed that desirable species are abundant and growing rapidly into larger size classes. It was concluded that bottomland hardwoods can be reproduced successfully by the seed-tree method or some other form of even-aged management. Furthermore, timber stand improvement (poisoning stumps and residual vegetation) was important in preparing the site for establishment and early growth of desirable seedlings.

——— **Stubbs, Jack, and Hook, D. D.**

1968. Stand development after a selection cutting in a hardwood bottom. South. Lumberman 217(2704): 126-128.

A selection cut was made in a 60-year-old bottomland hardwood stand. This cut was the first step in placing the stand under many-aged management. Culls and undesirable, nonmerchantable trees were poisoned the next year. Results of the cut and subsequent timber stand improvement (TSI) work were followed for 10 years. Levels of growing stock were severely reduced by losses of saplings and poles during logging. Quality degrade of the high value butt log, caused by logging damage and epicormic branching, occurred on almost 40 percent of sweetgum and cherrybark oak residual sawtimber. Volume growth of the residual stand was less than 3 percent per year. Reproduction was abundant in the stand before and after harvest, and desirable species outnumbered less-desirable species in the seedling size class. Unfortunately, the more tolerant, less-desirable species grew into larger classes much faster than desirable species. The latter were obviously not favored in the small openings created by the selection cut. We concluded that the selection cut did not achieve our management objectives, which were attaining an optimum level of growing stock, and increasing the proportion of desirable species in the stand.

DCoste, J. H., and Sackett, S. S.

1966. Baptism by fire. South. Lumberman 213(2656): 169-170.

The U. S. Forest Service's newly commissioned Mobile Fire Laboratory received its baptism on the 7,400-acre Gaston Fire in South Carolina during one of the state's worst spring fire seasons. Documentation of such fires is of value in substantiating laboratory findings, improving our understanding of fire behavior, and thereby increasing our ability to control wildfires more effectively.

DeCoste, J. H., Wade, D. D., and Deeming, J. E.

1968. The Gaston Fire. Southeast. Forest Exp. Sta., U.S.D.A. Fore Serv. Res. Pap. SE-43, 36 pp.

On April 1 and 2, 1966, the Gaston Fire burned 7,400 acres i the sandhills, 20 miles south of Columbia, South Carolina. The fir an intense, fast-moving conflagration, occurred during one of tl worst fire periods in South Carolina's history.

This paper presents data on fuels, fire behavior, weather, co trol activities, and fire effects collected at the fire site by a tea of scientists from the Southern Forest Fire Laboratory. Also i cluded is a brief account of the meteorological events which pr duced the drought and the severe burning conditions encountere

Della-Bianca, Lino, and Johnson, F. W.

1965. Effect of an intensive cleaning on deer-browse production in th southern Appalachians. J. Wildlife Manage. 29: 729-733.

The substantial increases in browse production and the hig quality, mixed hardwood stand that result on better sites followin intensive cleaning indicate that this silvicultural treatment may b of value to managers interested in multiple use management.

——— **and Wells, C. G.**

1967. Some chemical properties of forest soils in the Virginia-Carolin Piedmont. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res Pap. SE-28, 16 pp.

Chemical properties are presented for a number of soils foun in hardwood and pine-hardwood upland forest stands in the Vir ginia-Carolina Piedmont. Well-stocked, second-growth stands dis tributed over an extensive area and having a wide range in site in dex were used for the study. Calcium contents were significantl different between soil series, but generally it was found that soi series or soil types are impractical for predicting nutrient levels.

Dickerhoof, H. E.

1968. Termites are working on people's minds. South. Lumberman 21 (2704): 152-154.

Forest Service surveys have revealed that most new-home buyers and many architects and builders do not have the facts about termites. They still believe the fallacy that concrete slab floor construction offers better protection from termites than wood crawl space construction. The termite threat is often associated as a disadvantage of using wood floor construction—contrary to documented research which shows that termites can be easily and inexpensively controlled with chemicals.

Dieterich, J. H.

1967. New technique speeds fire line construction. South. Lumberman 215(2680): 177-178.

A new method of fireline construction is being tested for use against large, fast-spreading wildfires. A 30-foot-wide chemical fireline is used in conjunction with a system of controlled strip head fires to quickly widen the effective firebreak ahead of the fire. The fire retardant chemical used is a 15-percent solution of DAP; the strip fires are set using drip torches or with remote ignition sources launched from the moving chemical tanker.

Dieterich, J. H.

1967. Wildfire detection in the United States — a review of current practices and a look into the future. XIV. IUFRO-Congr. Proc. Vol. V (Sect. 24) Munich, 1967: 702-723.

This paper provides a general summary of some of the current practices, and common problems, involved in detecting wildland fires in the United States. Basic considerations are listed for establishing and maintaining an effective wildfire detection system; examples of effective wildfire detection systems currently in use are cited, and problems of converting from one detection system to another are discussed.

The review emphasizes the need for a common approach to solving the fire detection problem, but recognizes that fire detection is a regional, sometimes local, problem requiring a careful analysis of all pertinent facts and the integration of these facts into the most economical, workable solution.

New advances are being made daily in fire detection and surveillance capabilities. These are briefly reviewed to provide a look at possible changes that might be expected in the future.

Dohany, A. L., and Heikkenen, H. J.

1968. Insects attacking mature loblolly pine cones in Georgia. Ga. Forest Res. Counc. Res. Pap. 53, 4 pp.

In 1962 and 1963, mature cones of loblolly pine, *Pinus taeda* L., were sampled in two pure natural stands in each of 12 Georgia counties; 5 of which were in the Piedmont Region and 7 in the Upper Coastal Plain. The cones were dissected and examined for insect infestation. Of the total cones collected in all counties in both years, 19 percent were attacked by larvae of the moth, *Dioryctria amatella* (Hulst). Flies, or midges, of the family Cecidomyiidae were found in 0.5 percent of the cones in 1962 and 1 percent of the cones in 1963. Seedworms, *Laspeyresia* spp., destroyed 2 and 4 percent of the seed in 1962 and 1963 cones, respectively.

Dorman, K. W.

1966. Forest tree improvement research in the South and Southeast. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-22, 90 pp.

The amount and scope of research with both softwoods and hardwoods are reported for 36 agencies or combinations of agency and geographic location. There are 305 projects or studies involving 20 forest tree genera and 39 research subjects. Of all investigations, 65 percent are with the genus *Pinus*, 4 percent with other softwoods, and 31 percent with some 15 hardwood genera. Of the work with *Pinus*, 9 percent involves shortleaf pine, 27 percent slash pine, 9 percent longleaf pine, 26 percent loblolly pine, and 29 percent eight other pine species, one variety, one natural hybrid, and *Pinus* in general.

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1966. Research programs with species other than yellow-poplar, sweetgum, cottonwoods, and oaks. Eighth South. Conf. Forest Tree Impr. Proc. 1965: 56-57.

A brief account of research on hardwood tree species by 17 research agencies throughout the South and Southeastern states.

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1966. We can double the volume of slash pine growth. Forest Farmer 26(2): 22-23. Also in AT-FA J. 29(3): 6-7, 12.

Selection and hybridization of trees with a good combination of desirable traits resulted in a gain in volume growth per unit area of more than 46 percent in young progeny.

Dorman, K. W.

1967. Need for total-tree concept. Ninth South. Conf. Forest Tree Impr. Proc. 1967: 27-30.

There is a need in tree breeding research to test and evaluate trees and stands of trees in addition to individual traits of trees. Tree breeding is essentially creative, and the single tree is the smallest unit breeders work with. Some problems in creative breeding needing attention by schools, silviculturists, and research people are discussed.

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1968. Faster growing trees are boon to the South. U. S. Dep. Agr. Yearbook 1968: 48-53.

The importance of breeding is stressed for improved volume growth in forest trees because of limitations on forest land area, increasing populations, and the expanding requirements of such forest industries as pulp and paper.

——— **and Kraus, J. F.**

1967. The Georgia seed orchard story: theory to first seedlings within 10 years. J. Forest. 65: 124-126.

The methods used and the parts played by private industry, state forestry and research agencies, state educational institutions, and Federal research agencies are described in a coordinated program to improve the genetic quality of forest tree nursery stock.

Douglass, J. E.

1966. Effects of species and arrangement of forests on evapotranspiration. Nat. Sci. Found. Advanced Sci. Seminar, Int. Symp. Forest Hydrol. Proc. 1965: 451-461.

Hydrologists seek to understand the process of evapotranspiration so that intelligent management of these losses is possible. This paper reviews work concerned with effects of species and their arrangement on evapotranspiration. Findings from early work are sometimes contradictory because of the range in soil, plant, and atmospheric conditions studied, but some generalizations can be made. Grasses usually use less water than forest species because of the shallower rooting habits of grass, but if evapotranspiration differences occur between forest species, they could not be detected except where rooting depths were unequal Evapotranspiration varies with stand density and vegetative height, at least in humid regions, and evapotranspiration probably varies with slope and aspect as well. But the effect of these factors on the evapotranspiration process changes as soil, vegetative, and atmospheric conditions change. Early work provided valuable information to guide development of more sharply defined research in evapotranspiration processes, but it is important that new research recognize the dynamic nature of the process and provide for measurement of the principal soil, plant, and atmospheric factors controlling evapotranspiration.

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1966. Research at the Coweeta Hydrologic Laboratory. Clemson Univ. Counc. on Hydrol., Hydrol. Activ. in the S. C. Reg. Conf. Proc. 1965: 11-17.

This paper reviews the Forest Service program in forest hydrology at the Coweeta Hydrologic Laboratory from 1935 through 1965. Examples are given of research in each of the four investigation fields—micrometeorology, soil-water relations, plant-water relations, and streamflow relations—and results of some experimental watershed cuttings and species conversions on water yield are highlighted.

Douglass, J. E.

1966. Volumetric calibration of neutron moisture probes. Soil Sci. Soc. Amer. Proc. 30: 541-544.

A volumetric method of estimating the slope (*b* coefficient) of a neutron moisture probe calibration curve is discussed. Coefficients obtained for three probes by this method did not differ significantly between soil series or between horizons within a series. Simply dividing the count rate in water by 100 gave a value virtually identical to the *b* coefficient determined volumetrically for these probes and soils. Agreement was excellent between measured outflow from a covered 182-cubic-meter soil model and outflow predicted from neutron measurements made with a volumetrically calibrated moisture probe.

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1967. Man, water, and the forest. Forest Farmer 26(5): 6-7, 18, 20.

This paper acquaints the reader with results of over 30 years of watershed experimentation at the Coweeta Hydrologic Laboratory and the application of these results to management of the forest for improved water yield. It also outlines basic and multiresource research which is planned to assure continuation of the plentiful high quality water supply from the Appalachian Mountains.

Downing, R. L.

1965. An unusual sex ratio in white-tailed deer. J. Wildlife Manage. 29: 884-885.

Breeding ages, sex ratios, and densities of white-tailed deer are described for a 746-acre enclosure at Albany, Georgia, where, over a 3-year period, 30 fawns were reared in the ratio of four bucks per doe. The nearly even sex ratio among adults invites consideration of the theory that the first service of a buck each year produces predominantly male offspring, while subsequent breedings produce predominantly female offspring.

Drooz, A. T.

1964. Aggregation affects color of fall cankerworm larvae. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-33, 2 pp.

Fall cankerworm larvae reared solitarily were light green, but those reared in groups had dark head capsules and a broad black mid-dorsal stripe.

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1964. Effect of monthly solarization on eggs of the elm spanworm, *Ennomos subsignarius* (Lepidoptera: Geometridae). Ann. Entomol. Soc. Amer. 57: 657.

Tests were run to learn during what months solarization of elm spanworm eggs might prove most lethal. Eggs solarized in August and September, and April and May were severely affected. Exposures during November through February did not affect normal hatch.

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1964. A source of elm spanworm egg parasites. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-34, 3 pp.

The egg parasite, *Telenomus alsophilae*, apparently issues from fall cankerworm eggs about mid-April and attacks elm spanworm eggs at this time. Spanworm eggs collected prior to April were not parasitized.

Drooz, A. T.

1965. Differential infection of elm spanworm and fall cankerworm by *Paecilomyces farinosus* (Dickson ex Fries) Brown & Smith. J. Invertebrate Pathol. 7: 108-109.

Elm spanworm larvae were killed *in toto* by the general entomogenous fungus, *Paecilomyces farinosus* (Dickson ex Fries) Brown & Smith, when they were reared in very high humidity. Fall cankerworm larvae reared under identical conditions of time, place, and technique did not become mycotic. Spanworm larvae in the field or reared in the laboratory were never found infected.

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1965. Elm spanworm head capsule widths and instars. J. Econ. Entomol. 58: 629-631.

The number of instars and head capsule widths were determined from reared elm spanworm larvae. This insect normally has 5 instars, but an occasional sixth may develop. Among the 5-instar larvae there was no overlap in head capsule widths between the instars.

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1965. Some relationships between host, egg potential, and pupal weight of the elm spanworm, *Ennomos subsignarius* (Lepidoptera: Geometridae). Ann. Entomol. Soc. Amer. 58: 243-245.

Female pupae of the elm spanworm are significantly heavier than males. The pupae of spanworms reared on northern red oak and white oak were not significantly different in weight, but those reared on pignut hickory were significantly heavier than those on either oak. As the pupal stage progressed, pupal weight declined. Spanworms reared on pignut hickory produced an average of 109 percent more eggs than those reared on the oaks, and pupal weight and egg potential were found to be closely correlated.

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1966. Color studies of reared elm spanworm larvae and pupae. Ann. Entomol. Soc. Amer. 59: 568-573.

A preliminary study showed that individually reared larvae were light, and aggregated larvae were dark. The possibility that pheromones controlled color was investigated and discounted. The color relationships between instars, rearing density, and paired rearings with fall cankerworm, *Alsophila pometaria* (Harris), are discussed.

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1966. Intrinsic and extrinsic factors that cause variability in wing length in the elm spanworm, *Ennomos subsignarius*. Ann. Entomol. Soc. Amer. 59: 1021-1022.

Results show that in addition to ultimate body weight and fecundity, the size of skeletal structures, such as the wings, is greatly influenced by different dietary qualities of various hosts. Even within the same host species, size differences in the somatic tissues of the elm spanworm may accrue by sex, defoliation history, and time of flushing as reflected in maturity of foliage.

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1966. Obtaining individual eggs from an egg-mass-depositing insect. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-57, 2 pp.

The elm spanworm oviposits in masses. When gauze-covered cages were used, many eggs were deposited individually, thus providing single eggs for study.

Drooz, A. T.

1966. Some effects of rearing density on the biology of the elm spanworm. Can. Entomol. 98: 83-87.

The elm spanworm, *Ennomos subsignarius* (Hübner), a defoliator of oaks and hickories in the Southern Appalachians, was reared under three population densities—one, two, and four larvae per cage. Females reared singly had significantly greater pupal weight and fecundity than those reared in groups.

——— **and Solomon, J. D.**

1964. Effects of solarization on elm spanworm eggs (Lepidoptera: Geometridae). Ann. Entomol. Soc. Amer. 57: 95-98.

The elm spanworm oviposits almost exclusively on the underside of branches. Experimentation showed this benefits egg hatch, because no eggs hatched among eggs exposed toward the zenith and decreasing numbers of eggs hatched when solarized clockwise from North to West.

Duvall, V. L., and Hilmon, J. B.

1965. New grazing research programs for southern forest ranges. J. Range Manage. 18: 132-136.

In recent decades, research has brought substantial improvement in cattle and forage management on cutover forest ranges in the South. Today, massive reforestation is complicating the problems of integrating grazing with timber growing, and research aims are shifting accordingly.

Ebel, B. H.

1964. The occurrence of *Ernobius granulatus* LeConte in aborted first-year cones of longleaf pine. J. Forest. 62: 404-405.

Many dead first-year longleaf pine cones in northeast Florida contained larvae of *Ernobius granulatus*. Data indicate that *E. granulatus* is a secondary invader in the already dead cones.

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1965. Control of thrips on slash pine female strobili. J. Forest. 63: 287-288.

Heptachlor was tested as a water emulsion for the control of a thrips, *Gnophothrips piniphilus* Cwfd., injurious to female strobili of slash pine, *Pinus elliottii* var. *elliottii* Engelm. Thrips injury to strobili was effectively minimized by 0.1 percent spray applied to individual strobili clusters and also by 0.05 percent spray applied periodically to entire trees in combination with the fungicide ferbam.

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1965. The *Dioryctria* coneworms of north Florida pines (Lepidoptera: Phycitidae). Ann. Entomol. Soc. Amer. 58: 623-630.

Details the biologies of the three *Dioryctria* coneworms as they occur in cones and vegetative parts of *Pinus elliottii* Engelm. and *P. palustris* Miller.

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1966. Rearing and occurrence of xyelid sawflies on slash and longleaf pines in north Florida (Hymenoptera: Xyelidae). Ann. Entomol. Soc. Amer. 59: 227-229.

Soil-filled clay pots, sunk in the ground, were used for rearing *Xyela pini* Rohwer from mature larvae taken on slash pine (*Pinus elliottii*), and *X. minor* Norton and *X. bakeri* Konow from larvae found on both slash pine and longleaf pine (*Pinus palustris*).

Ebel, B. H.

1967. Arctiid cutworm-type destruction of slash pine seedlings. J. Forest. 65: 33.

Arctiid caterpillars associated with seedling-felling of slash pine in experimental plots at Olustee, Florida, were reared and identified as *Apantesis radians* Wlk. Such damage could be of importance in establishing slash (or other) pines by seeding methods.

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1967. Piedmont hardwoods—which do wood borers damage? South. Lumberman 215(2680): 113-114.

A study of logs and lumber was made at 12 Georgia Piedmont area sawmills to determine the relative extent of borer damage to the various commercial hardwoods.

We found yellow-poplar and sweetgum, of the more prevalent tree species, were nearly free of damage. Most other species, including the common oaks, showed light to moderate borer-caused defect. Piedmont hickory and red maple were frequently and extensively damaged.

——— and Kormanik, P. P.

1966. *Stictocephala militaris*, a membracid (Homoptera) associated with sweetgum, *Liquidambar styraciflua.* Ann. Entomol. Soc. Amer. 59: 600-601.

Insect eggs were found inserted into the meristem tissue of overwintering sweetgum buds in north Georgia. Rearings from these eggs were made and the insect was identified as a membracid, *Stictocephala militaris* (Gibson and Wells). This treehopper, for which host plants were not previously recorded, remained on sweetgum leaves and shoots throughout its entire life cycle. It occurs as a single generation a year.

——— and Merkel, E. P.

1967. *Hylobius* weevil larvae attack roots of young slash pines. Forest Sci. 13: 97-99.

Weevil larvae (*Hylobius* sp.) were found in the root systems of young slash pines (*Pinus elliottii* Engelm.) in south Georgia. Infested trees died as larvae reached maturity. This type of *Hylobius* infestation has not been previously recorded on southern pines, but resembles attacks by *H. rhizophagus* Millers *et al.* in northeastern America. The attacks occurred mainly on pines growing in disturbed soil and might become a problem in southern pine plantations established on prepared sites.

Eickhoff, W. D., and Robinson, V. L.

1966. Builder preferences for certain structural materials used in Georgia homes. Ga. Agr. Exp. Sta. Bull. N.S. 182, 13 pp.

Personal interviews with 87 builders located in six metropolitan areas of Georgia provided insight into the reasons underlying the builders' choice of materials used in residential home construction, with particular emphasis upon why southern pine dimension and board lumber was or was not used.

Fasick, C. A.

1968. Costs and returns to determine pulpwood or sawtimber rotation for pine plantations. 7th Auburn Forest. Forum Proc. 1968: 53-64.

Investment decisions in growing timber for pulpwood or sawtimber rotations involve complex economic analyses. The optimum rotation length for alternative products is determined by the individual goals of the investor, the alternatives available to him, present market prices, and the investor's future expectations.

Fasick, C. A., and Sampson, G. R.

1968. Can mathematical programming improve sawmill profits? South. Lumberman 217(2704): 155-156.

Mathematical programming can be a valuable technique to provide accurate information for sawmill managers. Practical solutions to complex problems can be determined by simultaneously considering many alternatives of operation and their restrictions. These solutions can help managers increase sawmill profits.

Fatzinger, C. W.

1964. Pine sawfly larvae, *Neodiprion excitans,* survive subfreezing temperatures in Florida. J. Econ. Entomol. 57: 412-413.

The effect of freezing temperatures on the survival of *Neodiprion excitans* larvae feeding on loblolly pine foliage was investigated. Larvae were found to pass from an active to a quiescent state when temperatures dropped below 40° F. Temperatures reaching a low of 16° F. killed 8 of 50 test larvae, demonstrating the larva's ability to withstand low winter temperatures.

——— **and Dixon, J. C.**

1965. Use of X-rays to detect southern pine beetles in shortleaf pine bark. J. Forest. 63: 451-455.

Beetles' images on radiographs of bark samples were counted and the results compared with the number of beetles found by dissection of the same species. Analysis of the data demonstrates approximately equal accuracy for X-ray and dissection methods; the X-ray method was more rapid and less expensive.

——— **and Proveaux, M. T.**

1965. Conversion equipment to produce a cyclic environment within constant temperature cabinets. Fla. Entomol. 48: 227-237.

Describes modification procedures so that a constant temperature cabinet can maintain combinations of constant temperature, light, and humidity (each independent of the intensity of the other); synchronous fluctuations of temperature and light, and humidity; and independent fluctuations of temperature and light during which humidity can be held at a constant level or be allowed to fluctuate with the temperature.

Fedde, G. F.

1964. Elm spanworm, a pest of hardwood forests in the southern Appalachians. J. Forest. 62: 102-106.

The distribution and past history of outbreaks in the United States, host relationships, life history, impact on forestry and related values, and control of the elm spanworm in the southern Appalachian Mountains.

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1965. The popular and scientific nomenclature of the elm spanworm, *Ennomos subsignarius* (Lepidoptera: Geometridae). Ann. Entomol. Soc. Amer. 58: 68-71.

Examines the various popular and scientific names applied to the spanworm, their origins, and the existing inconsistencies.

Gaby, L. I.

1966. Hot-wire smoke streams for visualization of air flow patterns. J. Sci. Instrum. 43: 334.

A simple electrical device can be used in a wind tunnel to produce nontoxic, noncorrosive, white smoke streams which can be seen and photographed easily.

Gaby, L. I.
1967. Controlled drying of pine roundwood. Forest Prod. J. 17(1): 19-23.

Peeled southern pine roundwood can be dried and conditioned rapidly when drying conditions are controlled.

Gansel, C. R.
1966. Inheritance of stem and branch characters in slash pine and relation to gum yield. Eighth South. Conf. Forest Tree Impr. Proc. 1965: 63-67.

Number of crooks per foot, degree of crook, size of branches, and crown width ratio were studied in ortets and their clones. The study proved that high gum yield and good form can readily be combined in a selection and breeding program.

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1967. Are genetic gains from seed-production areas small? J. Forest. 65: 634-635.

Total height, d.b.h., number of crooks per foot, degree of crook, and crown width ratio were studied in comparing progenies from two seed-production areas against progenies from randomly selected trees in adjacent stands. At 5 years of age, progenies from seed-production area trees had fewer crooks than progenies from the adjacent stand trees; however, no significant differences were found in any of the other traits studied.

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1967. Do wet- and dry-site ecotypes exist in slash pine? Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-69, 4 pp.

Progenies from a wet and a dry seed source were planted on wet and dry sites at each of two localities, one in north Florida and one in south Florida. After nine growing seasons in the field, no meaningful differences due to seed source were found for survival, total height, d.b.h., or incidence of diseases and insects. If wet- and dry-site ecotypes do exist, this study suggests that they are of minor importance.

——— **and Darby, Sanford**
1966. Development of multi-purpose superior slash pine forges ahead. South. Lumberman 213(2656): 144-145.

The Naval Stores and Timber Production Laboratory at Olustee, Florida, has enlisted the cooperation of most of the organizations in the South having superior slash pine selections, to develop a strain of slash pine with superior form, growth rate, timber quality, and gum yielding ability.

Gartman, J. C., and Clements, R. W.
1967. Gum farming profitable with acid paste. AT-FA J. 30(3): 7.

"Gum farming is a profitable business since acid paste was introduced," relates gum farmer J. C. Gartman. He cites his experiences and recommends the use of acid paste to the producer who is short of labor and has to pay high wages.

Gentry, T. R., and Wilson, E. T., Jr.
1966. A technique for rapid collection of balsam woolly aphid eggs. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-58, 2 pp.

Eggs of the balsam woolly aphid were brushed from the bark of Fraser fir with an artist's brush. The eggs were screened through six layers of women's nylon hosiery, which removed most adult aphids, waxy secretions, and bark scales.

Goebel, N. B., Brender, E. V., and Cooper, R. W.

1967. Prescribed burning of pine-hardwood stands in the Upper Piedmont of South Carolina. Clemson Univ., S. C. Agr. Exp. Sta., Forest Res. Ser. 16, 24 pp.

Spring burns were significantly better than summer burns in bringing about top-kill of small hardwoods, 1- to 3-inches d.b.h., in shortleaf pine-hardwood stands in South Carolina's Upper Piedmont. Direct seeding with loblolly pine resulted in a first year milacre stocking of 53 percent on the burned and 18 percent on the unburned plots. The advantages of a fire-prepared seedbed were particularly evident during poor survival years. Soil movement following fire treatments was negligible on the slopes involved.

Gooding, G. V., Jr.

1964. Effect of temperature on growth and survival of *Fomes annosus* in freshly cut pine bolts. (Abstr.) Phytopathology 54: 893-894.

Temperature effects on infection by *Fomes annosus* were studied under controlled laboratory conditions. Suppression of *F. annosus* by other fungi at 35° C. and its death at 40° C. indicated that high temperatures in nature may play an important role in survival of *F. annosus* in stumps.

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1966. Preparation of macromolecular antigens from *Fomes annosus*. Phytopathology 56: 1310-1311.

Macromolecules, presumably ribosomes, from *Fomes annosus* were found to be a good source of antigen. Macromolecular antigen, when allowed to react with an antiserum prepared against a crude fungus extract in an Ouchterlony plate, combined with antibody to form a single line of precipitation. When the same antiserum was allowed to react with crude fungal extract—homologous system—many lines of precipitation formed. It was suggested that macromolecules might have some advantage over crude extract in comparative serological studies.

——— **Hodges, C. S., Jr., and Ross, E. W.**

1966. Effect of temperature on growth and survival of *Fomes annosus*. Forest Sci. 12: 325-333.

The effect of temperature on growth rate and inactivation of *Fomes annosus* (Fr.) Karst. was determined in freshly cut stem sections of *Pinus taeda* L. Actively growing mycelium in wood chips was killed in less than 2 hours at 40° C. Preliminary data indicated that stump surface temperatures reached 40° C. or higher for periods of at least 2 hours on more than 50 percent of the days from May to August, thus providing one explanation of why less stump colonization by *F. annosus* occurs in parts of the southeastern United States during summer than other seasons.

——— **and Powers, H. R., Jr.**

1964. Serological comparison of *Cronartium fusiforme, C. cerebrum,* and *C. ribicola*. (Abstr.) Phytopathology 54: 622-623.

The relationship between three species of Cronartium was determined serologically, using antigen-antibody reactions in rabbits. All three fungi were found to be closely related, but *C. fusiforme* and *C. cerebrum* contained all antigenic sites of *C. ribicola*, plus one or more sites. *C. fusiforme* contained one or more sites not contained by *C. cerebrum*.

——— **and Powers, H. R., Jr.**

1965. Serological comparison of *Cronartium fusiforme, C. quercuum,* and *C. ribicola* by immunodiffusion tests. Phytopathology 55: 670-674.

Three closely related species of *Cronartium* were differentiated by use of serological techniques. Each of the three species were found to differ by at least one antigen.

Grosenbaugh, L. R.

1968. Sample-tree-measurement: a new science. Forest Farmer 28(3): 10-11.

Recent advances in the techniques for measuring timber employ 3P sampling, dendrometry, a trio or a pair of primary units of measure, and high-speed computers. These techniques eliminate need for using volume tables or for scaling felled timber. Product-yield, value, and cost can be linearly related to combinations of volume, surface, length, and weight much more satisfactorily than to traditional units of measure, such as board-feet or cords.

Grzenda, A. R., Nicholson, H. P., Teasley, J. I., and Patric, J. H.

1964. DDT residues in mountain stream water as influenced by treatment practices. J. Econ. Entomol. 57: 615-618.

Compares DDT residues in Coweeta streams after spraying for elm spanworm by airplane (1961) and by helicopter (1962). DDT contamination of Coweeta Creek was negligible after precise helicopter application on infestations in upslope and ridge areas.

Haasis, F. A., Marx, D. H., and Nelson, R. R.

1966. Morphological and physiological characteristics of mating types of *Phytophthora cambivora*. (Abstr.) J. Elisha Mitchell Sci. Soc. 82 (2): 87.

The physiological and morphological characteristics of 15 world isolates of *Phytophthora cambivora* were compared. Cardinal temperatures are given for the four major cultural types distinguished. Identifying descriptions are given for sporangia, chlamydospores, and oospores.

——— **Nelson, R. R., and Marx, D. H.**

1964. Morphological and physiological characteristics of mating types of *Phytophthora cinnamomi*. Phytopathology 54: 1146-1151.

Studies on morphological and physiological characteristics of *Phytophthora cinnamomi* lead to the conclusion that the isolates studied constitute components of a single biological species.

——— **Nelson, R. R., and Marx, D. H.**

1965. Occurrence of mating types in *Phytophthora cambivora*. (Abstr.) J. Elisha Mitchell Sci. Soc. 81(2): 75.

Reports for the first time the intraspecific mating reactions between plus and minus strains of the heterothallic fungus *P. cambivora*. Characteristic warty (protruded) oospores were produced in paired compatible cultures which constitute an important and previously unavailable criterion in evaluating sampled isolates as representatives of *P. cambivora.*

Haines, W. H. B.

1967. Forest statistics for the Piedmont of South Carolina, 1967. Southeast. Forest Exp. Sta., U. S. Forest Serv. Resource Bull. SE-9, 35 pp.

Area of commercial forest land in the South Carolina Piedmont has increased from 4.1 to almost 4.5 million acres since the last survey in 1958. Area in pine and oak-pine types has increased from 63 to almost 72 percent of the commercial forest. Volume of softwood timber, which had been decreasing before 1958, has increased by 23 percent. Hardwood volume continues to increase, and at a faster rate than between the two previous surveys. In 1966 growth of all timber exceeded timber removals by 46 percent.

Haines, W. H. B.

1968. Pulpwood prices in the Southeast, 1962-1967. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Note SE-92, 2 pp.

Average prices paid for both pine and hardwood bolts from all sources increased by about 16 percent between 1962 and 1967—from $16.55 to $19.25 per cord for pine, and from $13.40 to $15.55 per cord for hardwood. Pine and hardwood chip prices increased by 17 and 22 percent, respectively, over the same period. Except for hardwood bolts, however, increases in pulpwood prices in 1967 were substantially below the increases in 1966.

Halls, L. K., Hughes, R. H., Rummell, R. S., and Southwell, B. L.

1964. Forage and cattle management in longleaf-slash pine forests. U. S. Dep. Agr. Farmers' Bull. 2199, 25 pp.

How to: (1) estimate amount and nutritional value of range forage available for cattle grazing at various seasons; (2) feed supplements and minerals when they are needed; (3) distribute the herd over the range; (4) prevent damage to timber, watersheds, and wildlife habitat; and (5) keep the herd healthy and productive.

Hammon, G. A., and McDonald, J. K.

1967. Recreation information management. Trends in Parks & Recreation 4(2): 29-32.

Describes a recreation information management system, called RIM, that provides a current and detailed picture of where and when recreation use is occurring on National Forest lands in relation to planned capacity. Fully automated, the RIM system provides a wide variety of descriptive data, such as the biological, physical, and aesthetic characteristics of land and water units. Data are also available on the amount and type of activities that occur on a given unit, and use is reported in terms of visitor-days. These data provide a precise and continuing description of the constantly changing use patterns on National Forests.

Harlow, R. F.

1967. On the same area - better deer herds—and better timber. Forest Farmer 26(6): 10, 23.

Even-aged management benefits both the timber manager and the game technician by increasing regeneration of the desirable timber species and deer forage supplies. Instead of anticipating less timber and deer in the future, under a clearcutting program, we can look forward to more timber and deer.

——— **and Downing, R. L.**

1968. Evaluating the deer track census method used in the Southeast. Twenty-first Annu. Conf. Southeast. Assoc. Game & Fish Commrs. Proc. 1967: 39-41.

An evaluation of published work on the deer track count census method indicates the popularly used 1:1 relationship between tracks across roads and number of deer on an area can be neither rejected nor accepted. The day-to-day variability in deer track crossings usually requires a large number of consecutive counts to detect changes in populations; procedures are presented.

——— **and Oliver, W. F., Jr.**

1968. Natural factors affecting deer movement. Quart. J. Fla. Acad. Sci. (1967) 30(3): 221-226.

Data were gathered and analyzed to evaluate effect of type of vegetation, moon phases, and weather on deer movement. Movement was determined by counting tracks of deer crossing selected 1-mile plots along graded roads. The analysis produced evidence that white-tailed deer of the Coastal Plain have a consistent pattern of movement, apparently not affected by fair weather conditions that prevailed during the counts nor by moon phases.

Harlow, R. F., and Palmer, Z. F.

1967. Clearcutting in coordinated deer-timber management in the Southern Appalachians. Wildlife in N. C. 31(12): 14-15.

A possible solution to the scarcity of deer food and a lack of adequate timber regeneration found throughout much of the Southern Appalachians is through even-aged management. One year following clearcutting, deer forage increased from an average of 50 pounds per acre outside cuttings to approximately 1,000 pounds per acre in the cut areas. Also timber seedlings increased from almost none outside cut areas to 2,247 per acre inside.

——— **Strode, D. D., and Oliphant, L. M.**

1966. Timber and deer thrive under even-aged hardwood management. South. Lumberman 213(2656): 118-120.

Clearcutting in the yellow-poplar cove and mixed oak forest cover types of the Southern Appalachians produced an abundance of seedlings and sprouts for timber regeneration as well as a plentiful supply of forage for deer.

Harms, W. R.

1968. Selecting a coniferous tree species for the Carolina sandhills. Forest Farmer 28(1): 10-11.

Lodgepole pine, jack pine, sand pine, spruce pine, Virginia pine, shortleaf pine, pond pine, longleaf pine, slash pine, loblolly pine, redcedar, and Arizona cypress were planted in a small comparison test in the South Carolina sandhills on Eustis and Lakeland deep sandy soils. Ten-year measurements show that, with the exception of lodgepole and jack pine, all species survived in adequate numbers. Slash and loblolly pine were the largest trees—loblolly being the tallest on the Eustis soil and slash the tallest on Lakeland soil. Slash pine is the preferred species for sandhills planting, but in this test loblolly appears to be equally suitable on good sites. Redcedar and Arizona cypress show promise as a source for Christmas trees in this area.

——— **and Collins, A. B. III**

1965. Spacing and twelve-year growth of slash pine. J. Forest. 63: 909-912.

Comparison at age 12 of eight spacings of old-field planted slash pine (*Pinus elliottii* Engelm.) shows average tree diameter is positively correlated with spacing. Through the seventh year relationship is linear; beginning in the eighth and intensifying through the twelfth year the relationship is curvilinear. Beginning with the eleventh year, tree height is positively correlated with spacing, although the trend is not entirely consistent. There is a positive curvilinear relationship between crown ratio and spacing.

Harrar, E. S., and Campbell, R. A.

1966. The major defects in southern hardwood veneer logs and bolts. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-19, 23 pp.

This pictures and describes visible defect indicators and explains their importance.

Harrington, T. A.

1964. Interim report on sulphuric acid paste. AT-FA J. 27(1): 8-9.

Sulfuric acid paste is a promising formulation for prolonging gum flow. Results from two producing seasons indicated gum yields from tri-weekly or monthly chipping intervals with paste were nearly as good as yields from bi-weekly chipping with the standard aqueous solution of sulfuric acid.

Harrington, T. A.

1964. New research in gum extraction methods. AT-FA J. 26(8): 6-8. Also, with title New research in gum extraction at Naval Stores & Timber Production Lab, in Nav. Stores Rev. 74(2): 6-7, 16.

Reports on the use of 2,4-D as a noncorrosive gum flow stimulant for producing high grade gum from slash pine. Using this stimulant, cup and gutter corrosion is held to a minimum. Preliminary results from the use of sulfuric acid paste are also presented. Paste promises to prolong gum flow, reduce cup and gutter corrosion, and permit consistent chemical treatment of the fresh streaks.

——— 1964. Reducing cost of producing pine gum. AT-FA J. 27(3): 8-11.

Basic and applied research program of the Naval Stores Production Research Project, with particular emphasis on costs.

——— 1965. Gum production research—a key to increased profits. Nav. Stores Rev. Int. Yearbook 1964: 20-21, 65.

Research results are presented that will lead to increased profits. Covered are prolonging gum flow, producing high grade gum, integrating gum and timber production, tree nutrition, and breeding high gum-yielding trees.

——— 1965. Planning for the future of gum naval stores. AT-FA J. 28(3): 9-12.

Reviews past contributions made to the gum naval stores industry by U. S. Forest Service research. Predicts type of future operations that may develop for producing gum.

——— 1965. Planting wetland species on upland soil. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-47, 2 pp.

Baldcypress, pondcypress, and blackgum can be successfully planted as bare-rooted 1-0 stock on upland soils in northeast Florida. After three growing seasons all planted trees were still alive, although height growth has been disappointingly slow.

——— 1965. Reducing the cost of producing crude pine gum. Nav. Stores Rev. 74(10): 6-7, 9-10, 17.

Reports on the basic and applied research program of the Naval Stores Production Research Project, with particular emphasis on investigations that promise to furnish means of reducing production costs.

——— 1966. Errors in use of acid paste, and suggested remedies. AT-FA J. 28(11): 18.

Simple remedies are presented for the most common mistakes made in using acid paste for gum production.

——— 1966. Gum production research—present and future. Nav. Stores Rev. Int. Yearbook 1965: 20-31, 65.

Research program with respect to problems currently facing the gum naval stores industry.

Harrington, T. A.

1966. Reducing the cost of producing crude pine gum. USDA Agr. Res. Serv., Nav. Stores Work Conf. Proc. 1964: 15-19.

Describes how basic research aimed at providing knowledge and understanding of the life processes involved in the synthesis and translocation of oleoresin by pine trees, and applied research on development and evaluation of gum extraction techniques and methods for commercial application, has resulted in high-yield gum trees and extraction that could increase production by 100 percent, while lowering costs.

———— 1966. Using acid paste—a new gum production technique. AT-FA J. 28 (8): 9-11. Also in Nav. Stores Rev. 76(2): 5-6, 17-18.

Sulfuric acid paste prolongs the flow of gum from slash and longleaf pines for periods of 3 and 4 weeks and increases the productive capacity of chipping labor.

———— 1967. Errors in use of acid paste and suggested remedies. AT-FA J. 29 (7): 10-11. Also, with title Errors in acid paste use, suggested remedies, in Nav. Stores Rev. 77(1): 8.

Simple remedies are presented for the most common mistakes made in using acid paste for gum production.

———— 1967. Explains how to use acid paste. Nav. Stores Rev. 76(12): 4-5, 7. Also, with title T. A. Harrington spoke at annual meeting, in AT-FA J. 29(8): 11-12.

The technique of using sulfuric acid paste as a gum flow stimulant is described. Special emphasis is given to some aspects of using paste that require particular attention.

———— 1968. Mechanizing gum naval stores. AT-FA J. 30(8): 4-8. Also, with title Mechanized gum naval stores—scientist outlines segments of program to speed up pine gum chipping, collecting, in Nav. Stores Rev. 78(3): 6-7, 11.

Results from preliminary trials indicate that a mechanized system for pine gum production, under development by the U. S. Forest Service, will greatly increase man-day production of laborers, improve working conditions, and increase the quality of the gum. Pilot plant evaluations of the system are scheduled for 1968.

———— **and Riebold, R. J.**

1967. The shelterwood method for regenerating sand pine. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-67, 2 pp.

Study results from the Ocala National Forest show that harvesting naturally regenerating sand pine (*Pinus clausa*) by the shelterwood method may have promise.

Hart, C. A., and Swindel, B. F.

1967. Notes on the laboratory sampling of macerated wood fibers. Tappi 50: 379-381.

With some commonly employed methods of selecting sample fibers from macerated material on a microscopic slide, the probability of a fiber being selected is related to the length of the fiber. It is shown that such methods can lead to substantial bias in the estimation of fiber properties, especially fiber length. Simple techniques of avoiding such a bias, employing either one or both fiber ends as selection criterion, are suggested.

Hatchell, G. E.

1966. Loblolly pine direct seeding in the lower Piedmont of Georgia. Ga. Forest Res. Counc. Res. Pap. 40, 4 pp.

Results of two studies, conducted in 1964 on the Hitchiti Experimental Forest near Macon, Georgia, indicate that for protection from drought early germination of loblolly pine is necessary. Broadcasting and spot-seeding stratified seed in mid-February resulted in high stocking of seedlings in the fall, but seeding in April, May, and June was unsuccessful. Stratified seed covered with ¼ inch of soil yielded higher germination and survival than surface sown seed or seed covered with ½ inch of soil; but covering unstratified seed caused low germination.

Hauck, C. A., and Taylor, D. F.

1968. Project THEO basic surface network. (Abstr.) Amer. Meteorol. Soc. Bull. 49: 59.

The Southern Forest Fire Laboratory is establishing a full-scale meteorological network in southeast Georgia under the Forest Fire Meteorology Project and Project THEO, a Navy-financed effort in fundamental investigations in coastline meteorology.

The basic surface network and instrumentation are described. Problem areas in establishing the network are discussed. Network data are described in terms of data processing and formats which will be available to the users.

Projected instrumentation is described in terms of scheduling, acquisition, and support.

Hebb, E. A., and McReynolds, R. D.

1968. A small electric water-level probe. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-87, 3 pp.

Describes a device for determining water levels that is simple in design, well-suited to rough field work, and small enough to fit in a briefcase. Cost is about $10.

Heikkenen, H. J.

1964. A *Dioryctria* spp. outbreak and its control in a loblolly-slash pine seed orchard. J. Forest. 62: 577-579.

A destructive cone and seed insect, *Dioryctria* spp., was discovered infesting fusiform cankers in a loblolly-slash pine seed orchard in Georgia. Control of the larvae was achieved with one percent gamma solution of BHC in a nonphytotoxic oil.

Helseth, F. A.

1968. Manometric measurement of turgor pressures in the bole of slash pine. (Abstr.) ASB Bull. [Assoc. Southeast. Biol.] 15(2): 40.

Oleoresin exudation pressure (O.E.P.) in slash pine (*Pinus elliottii* Engelm.) results from (1) the quantity of oleoresin in the duct and (2) turgor pressure changes in the epithelial cells lining the ducts. The quantity of oleoresin in a single tree can be considered as constant for short periods of time. However, there is considerable variation among trees which may influence the minimum O.E.P.

The diurnal patterns of O.E.P. clearly reflect dehydration and rehydration of cells and tissues. Pressures are maximal (9-12 atm.) just at dawn and minimal (3-5 atm.) in the afternoon, corresponding to increases in moisture stress. Upon opening of the stomates in the morning, pressures begin to decrease rapidly in the upper crown, proceeding basipetally with the transmission of moisture tensions down the bole. These diurnal pressure changes are positively correlated with atmospheric relative humidity and negatively correlated with changes in temperature and needle moisture stress (by pressure bomb). Pressures at the base of the bole normally exceed those in the crown, the gradient usually approximating 1 atm./10 m. at night and increasing during the day.

Helvey, J. D.

1964. Rainfall interception by hardwood forest litter in the southern Appalachians. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res Pap. SE-8, 9 pp.

Moisture interception by hardwood litter was measured durin 1961 and 1962. The maximum field water content—water retaine against drainage—averaged 215 percent of ovendry weight. Abou 1 inch of throughfall was required to wet the litter to this maximum The amount of water evaporated per month from litter was greate during the dormant season. Interception loss during 1962 was abou 2.2 inches and the long-term average is estimated to be about inches.

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1967. Interception by eastern white pine. Water Resources Res. 3: 723-729

Measurements of gross rainfall, throughfall, stemflow, and litte interception in three eastern white pine stands, age 10, 35, and 6 years, in the Southern Appalachians of western North Carolina, wer used to derive regression equations for estimating throughfall, stemflow, and the sum of throughfall and stemflow from measurements o gross rainfall. Equations for total interception loss were derive by algebraically combining losses from the canopy and litter. Thes equations were used to predict total seasonal interception loss (I from measurements of total seasonal rainfall (ΣP) and number o storms (N). Equations for the 10-, 35-, and 60-year-old stand are $I = 0.05(N) + 0.08(\Sigma P)$, $I = 0.05(N) + 0.12(\Sigma P)$, an $I = 0.06(N) + 0.18\ (\Sigma P)$, respectively. Total interception loss i white pine increased with stand age, and total loss from all pin stands studied exceeded losses calculated for mature hardwoods During the dormant season, calculated monthly interception los from mature hardwoods and white pine exceeded potential evapotranspiration calculated by the Thornthwaite method.

——— **and Patric, J. H.**

1965. Canopy and litter interception of rainfall by hardwoods of easter United States. Water Resources Res. 1: 193-206.

Results from all available studies of rainfall interception b hardwoods of eastern United States vary over a small range. Regression equations are presented describing the relation betwee gross rainfall, throughfall, and stemflow for growing and dorman seasons.

——— **and Patric, J. H.**

1966. Design criteria for interception studies. Int. Assoc. Sci. Hydrol Bull. 67: 131-137.

Rain intercepted by forest vegetation is an important loss o water. Although interception has been widely studied, variation i sampling intensity, sampling methods, and data analysis often prevents cross comparison of study results. This report, gleaned fron over fifty studies, defines variability of interception parameter and provides sampling designs for obtaining estimates to selecte levels of probability for each parameter mean.

Hendrix, F. F., Jr., and Campbell, W. A.

1966. Root rot organisms isolated from ornamental plants in Georgia U. S. Dep. Agr. Plant Dis. Rep. 50: 393-395.

Two species of *Phytophthora* and 13 species of *Pythium* wer isolated from roots and soil. *Rhizoctonia* spp. were also relativel common. Most of the plants had symptoms typical of reduced roo systems. Apparently these fungi are not rapid killers but caus mainly slow growth and general chlorosis.

Hendrix, F. F., Jr., and Campbell, W. A.
1968. A new heterothallic *Pythium* from the United States and Canada. Mycologia 60: 802-805.

Pythium heterothallicum is described as a new species. The species designation "heterothallicum" was chosen to emphasize the absence of homothallic isolates, in contrast to *P. sylvaticum* in which isolates with varying degrees of homothallism occur. *P. heterothallicum* will not mate with any of the tester strains of *P. sylvaticum* found to date. It differs morphologically from *P. sylvaticum* in possessing a larger number of antheridial branches and antheridia. It also grows much slower at 25° C., averaging only 1.5 cm. of radial growth in 24 hr. in contrast to *P. sylvaticum* which averages 2.6 cm. *P. heterothallicum* will not grow at 35° C. while *P. sylvaticum* makes slight growth.

——— **and Campbell, W. A.**
1968. Pythiaceous fungi isolated from southern forest nursery soils and their pathogenicity to pine seedlings. Forest Sci. 14: 292-297.

Pythium irregulare-debaryanum, P. sylvaticum, P. spinosum, P. helicoides, P. splendens, and *Phytophthora cinnamomi* were isolated from soil in forest nurseries in the Southeastern United States. These fungi caused post-emergence damping-off of seedlings of *Pinus echinata, P. elliottii,* and *P. taeda* in greenhouse tests. Necrosis of feeder roots in surviving seedlings resulted in a reduction of the root and shoot systems. *P. echinata* was most susceptible to damping-off, followed by *P. taeda* and *P. elliottii.* Susceptibility to feeder root necrosis varied with the species of *Pythium* tested.

——— **and Kuhlman, E. G.**
1964. Root infection of *Pinus elliottii* by *Fomes annosus.* Nature 201 (4914): 55-56.

Studies in slash pine plantations demonstrated direct infection of roots by *Fomes annosus.* It was concluded that infection probably does occur more frequently through stump surfaces, but the occurrence of direct root infection means stump protectants will not necessarily give complete protection against *F. annosus.*

——— **and Kuhlman, E. G.**
1965. Factors affecting direct recovery of *Phytophthora cinnamomi* from soil. Phytopathology 55: 1183-1187.

Describes a medium for recovery of *P. cinnamomi* from the soil and presents data on the population of *P. cinnamomi* in naturally infested soil as collected by the soil dilution medium and the Campbell apple technique.

——— **Kuhlman, E. G., Hodges, C. S., Jr., and Ross, E. W.**
1964. *Fomes annosus*—a serious threat to regeneration of pine. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-24, 4 pp.

Fomes annosus was fairly widespread among planted pines on sites where annosus root rot had been so severe that the original stand had been clearcut. Infection also ran as high as 6 percent on a site originally supporting a longleaf-scrub oak stand, and excavations showed disease spread by root contact between infected stump roots and seedling roots.

——— **Powell, W. M., Owen, J. H., and Campbell, W. A.**
1965. Pathogens associated with diseased peach roots. (Abstr.) Phytopathology 55: 1061.

Peach decline has sharply reduced the number of bearing trees in Georgia. *Pythium irregulare* was isolated from 91 percent of the orchards; fourteen other *Pythium* species were isolated in lesser numbers. *Pythium*-infected trees were found in 92 percent of the orchards, and several species of nematodes were also prevalent.

Hepting, G. H.

1964. Damage to forests from air pollution. J. Forest. 62: 630-634.

Past air pollution damage was mainly caused by SO_2 and F from smelting. Current damage is also the result of oxidant from photochemical smog, possibly natural ozone, and certain industrial stack gases. Means of detecting pollution by use of sensitive clonal lines of white pine have been developed.

———— 1964. Forest pathology in the southern Appalachians, 1900-1940. Forest Hist. 8(3): 11-13.

A chronicle of the people involved in research in forest diseases in the Appalachian Mountains with dates, names, and activities, from 1900 until the end of the C.C.C. era in 1940.

———— 1964. Forestry gains from basic research. Va. Forests 18(4): 8-11, 22, 24.

The importance of basic research in forestry, in order to progress in applied research, is emphasized. Several examples are given of how recent fundamental discoveries have opened new doors to progress in forestry.

———— 1965. Codes to the INTREDIS register system for literature retrieval in forest pathology. USDA Forest Serv. Southeast. Forest Exp. Sta., 61 pp.

The International Tree Disease (INTREDIS) Register is a system of electronic literature retrieval designed to provide literature lists by various categories for workers anywhere in the world. Punchcards are coded for forest pathology literature in accordance with the codes given in this booklet. The field of forest pathology is divided into more than a hundred subject segments each with a code number, over 2,600 host plant genera or species (worldwide), between 700 and 800 causal organism genera or species, and nearly 50 continents, countries or other geographic separations.

———— 1965. The importance of forest diseases and insects. *In* FAO/IUFRO symposium on internationally dangerous forest diseases and insects. Unasylva 19(3): 99-102.

One of a series of papers summarizing the world forest disease and insect meeting at Oxford, England. Many diseases and insects are named and some measure of their destructiveness is given. While timber volume losses in terms of decay and mortality are greatest in the old-growth natural stands of the world, the main concern of the future centers on new problems associated with man-made forests, the use of exotic species, monoculture, and large plantings of uniform age.

———— 1966. Air pollution impacts to some important species of pine. J. Air Pollut. Contr. Assoc. 16: 63-65.

This is a review of reports of damage (1) to ponderosa pine from smog in California and from fluoride in Washington, (2) to eastern white pine from fumes from coal- and oil-burning power plants and from oxidant of unknown origin, (3) to *Pinus pinea* from urban smog in Rome, (4) to hard pines near incinerators in the East, and (5) to conifers elsewhere in the world.

Hepting, G. H.

1966. Appraisal and prediction of international forest disease hazards. FAO/IUFRO Symp. Int. Dangerous Forest Dis. & Insects (1964) 1 (12377/E): 1-12.

A method is presented by which the pathologists in a given country or region can determine which of their forest diseases pose a threat to the forest species of other lands, and which of the diseases studied in other countries pose a threat to them. The likelihood that any disease serious in one country or region will be a threat to another area is estimated on the basis of the climatic, host, soil, and other factors known to limit a given pathogen, or to make it aggressive. Several examples are given.

———— 1966. The INTREDIS register for world literature retrieval in forest pathology. FAO/IUFRO Symp. Int. Dangerous Forest Dis. & Insects (1964) 2 (12379/F): 1-8.

An electronic system of literature retrieval is proposed for the field of forest pathology. It would make available to any qualified scientist a list of citations to the main world's literature. Requests could be made either by subject (e.g., root rots or seed diseases), or host plant (e.g., *Pinus strobus* or *Picea abies*), or causal organism (e.g., *Fomes annosus* or *Pseudomonas syringae*), or country, or author. This system, called the INTREDIS Register, is now in operation.

———— 1967. Diagnosis of forest diseases. USDA Forest Serv., S&PF, SA, Fourth Forest Insect & Dis. Contr. Work Conf. Proc., Atlanta, 1967: 208-212.

The steps used in diagnosing tree diseases are outlined. These involve mainly determination of host and pathogen or physiogen, laboratory techniques to uncover the cause, the use of monographs, books, herbaria, and institutions that specialize on certain organisms. Emphasis is placed on how far the general diagnostician is likely to get by himself, and at what point he may need the specialist. Some common causes of error in diagnosis are indicated.

———— 1967. International tree disease register. Agr. Sci. Rev. 5(1): 33-34.

INTREDIS, which is the abbreviation of International Tree Disease, is a system of electronic, computerized literature citation storage and retrieval for the field of forest pathology, containing on magnetic tape 16,000 references to tree disease literature. Within a half hour from receipt of a request a list of citations can be provided by subject, tree species, causal organism if any, country, year, or author, or any combination of these.

———— 1967. The INTREDIS register for literature retrieval in forest pathology. XIV. IUFRO-Congr. Proc. Vol. V (Sect. 24) Munich, 1967: 385-387.

The INTREDIS register is a system of electronic data retrieval for the field of forest pathology, operated by the U. S. Forest Service and the Canada Department of Forestry. It is composed of two elements: (1) A set of punchcards, each containing a reference to an abstracted article on some phase of tree disease or forest products pathology, and (2) a computer system that provides for putting the punchcard information on magnetic tape, and for scanning the tape and printing out, electronically, a list of references in accordance with the nature of the request. The computer program allows for printouts to be provided by subject, tree species or genus, causal organism, country, year of publication, author, or abstract journal. The tapes now contain over 18,000 references to literature citations in the field of forest pathology.

Hepting, G. H.

1967. Measuring losses from forest diseases. XIV. IUFRO-Congr. Proc. Vol. V (Sect. 24) Munich, 1967: 325-326.

Our FAO/IUFRO Oxford meeting in 1964 recommended that all nations make greater efforts to quantify their losses from forest diseases in order that we can know where best to place our research and control efforts. Many forest policy decisions hinge upon the extent to which a country can raise its timber production by reducing the losses from destructive agents, among which disease is one of the most damaging. This session on quantification was scheduled to explore what progress has been made in the past 3 years toward obtaining better measures of damage from tree diseases around the world. The U. S. Forest Service is intensively studying the methodology of getting better quantification of losses from destructive agents, using the most modern statistical and computer techniques. Our Timber Resource Review figures on losses from forest diseases are still the best we have, but we are working toward better estimates of all losses from forest enemies.

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1968. Diseases of forest and tree crops caused by air pollutants. Phytopathology 58: 1098-1101.

In many ways, air pollution is becoming an important aspect of forest pathology. Trees over large areas of the United States are heavily damaged by polluted air carrying either sulfur oxides, fluorides, or oxidants. All forested regions have suffered some damage (examples are given) because of the rapid increase in consumption of fossil fuels and the enormous growth of our automobile population. While trees can be damaged by polluted air, they can also fight against a poisoned atmosphere by serving as sensitive, selective monitors. Also, some tree types can withstand high levels of pollution, and can be planted in polluted areas to serve as ameliorating agents. Included is discussion of the role of trees in causing pollution—atmospheric haze—by their aromatic hydrocarbons combining with nitrogen oxides in the presence of sunlight.

Hewlett, J. D.

1964. Research in hydrology of forested headwaters of the Coweeta Hydrologic Laboratory. Twenty-Ninth N. Amer. Wildlife & Natur. Resources Conf. Trans. 1964: 103-112.

Background and review of forest hydrology research at Coweeta, and plans for future staffing and research.

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1964. Water or forest—can we have all we need of both? Frontiers Plant Sci. 17: 2-3.

Sketches a recent experiment with a transpiration inhibitor and cites benefits possible if this or related tests succeed.

——— **and Douglass, J. E.**

1968. Blending forest uses. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Pap. SE-37, 15 pp.

Compatibility of forest management practices on a 356-acre Southern Appalachian watershed is examined in this unique experiment to determine the feasibility of intensive management for wood, water, wildlife, and recreation. An efficient and stable access system is stressed, and the effect of various woods practices on the four basic resources is rated. Increases are shown in water yield, game forage, quality timber growth, and general use of the area. Some unresolved conflicts among uses of the forest are revealed.

Hewlett, J. D., Douglass, J. E., and Clutter, J. L.

1964. Instrumental and soil moisture variance using the neutron-scattering method. Soil Sci. 97: 19-24.

The variation of soil moisture estimates determined by the neutron-scattering method is examined in theory and a statistical model is developed to account for error. Instrument and timing errors are shown to contribute insignificantly to the standard error of estimate in sampling studies. Their contribution to estimates of moisture change with time is also negligible.

——— **and Hibbert, A. R.**

1966. Factors affecting the response of small watersheds to precipitation in humid areas. Nat. Sci. Found. Advanced Sci. Seminar, Int. Symp. Forest Hydrol. Proc. 1965: 275-290.

A numerical rating system, the response factor, was developed from precipitation and streamflow records for use in classifying the hydrologic response of small watersheds in humid areas. Long-term hydrograph records from 15 forested watersheds in eastern United States were separated into quick and delayed flow by computer and ranked according to mean precipitation, quick flow, and the response factors quick flow/precipitation and quick flow/total water yield.

Hibbert, A. R.

1966. Forest treatment effects on water yield. Nat. Sci. Found. Advanced Sci. Seminar, Int. Symp. Forest Hydrol. Proc. 1965: 527-543.

Results are reported for 39 studies of the effect of altering forest cover on water yield. Taken collectively, these studies reveal that forest reduction increases water yield, and that reforestation decreases water yield. Results of individual treatments vary widely and for the most part are unpredictable.

——— **and Cunningham, G. B.**

1966. Streamflow data processing opportunities and application. Nat. Sci. Found. Advanced Sci. Seminar, Int. Symp. Forest Hydrol. Proc. 1965: 725-736.

Techniques used at the Coweeta Hydrologic Laboratory for processing streamflow records from recorder charts and analog-to-digital recorder tapes to final discharge integration are discussed in detail. A computer method is presented for separating the stream hydrograph into parameters useful for evaluation and comparisons of streamflow response.

Hilmon, J. B.

1964. Plants of the Caloosa Experimental Range. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-12, 24 pp.

A checklist of 189 vascular plants on the south Florida range and a brief introduction to their abundance, forage value, and habitats. Only three grasses—pineland threeawn, yellowsedge bluestem, and goobergrass—are abundant and good forage for cattle.

——— **and Douglass, J. E.**

1968. Potential impact of forest fertilization on range, wildlife, and watershed management, pp. 197-202. *In* Forest fertilization theory and practice symposium 1967. Tenn. Val. Authority, Muscle Shoals, Ala.

The impacts of fertilizers on forest ecosystems are considerable and reach far beyond effects on tree species. Yield and quality of cattle forage and wildlife food plants may be increased significantly by fertilization. These beneficial responses may be partially offset by animal damage to trees. Composition of plants in the understory may be altered and the rate or direction of plant succession affected. On upland forest ecosystems, at least, water yield may drop sharply after fertilization; but most available evidence indicates water quality is unaffected.

Hilmon, J. B., and Hughes, R. H.

1965. Fire and forage in the wiregrass type. J. Range Manage. 18: 251-254.

The effects of fire on major range plants and how the use of fire is changing are reviewed. Burning increases the availability and usefulness of the early growing wiregrasses during the winter and spring. Adaptation to sprout quickly after fire and early decline in quality and palatability maintain or increase the abundance of wiregrasses in the type.

———— and Hughes, R. H.

1965. Forest Service research on the use of fire in livestock management in the South. Fourth Annu. Tall Timbers Fire Ecol. Conf. Proc. 1965: 260-275.

Management technology and fire ecology of major herbs and shrubs for the pine-cane, pine-bluestem, and pine-wiregrass types are reviewed.

Hodges, C. S.

1964. The effect of competition by *Peniophora gigantea* on the growth of *Fomes annosus* in stumps and roots. (Abstr.) Phytopathology 54: 623.

Growth and development of *Fomes annosus* and competing fungi in stumps and roots were followed for a year after cutting. After 2 months, almost two-thirds of the stumps were infected with *F. annosus*. After 1 year, however, *F. annosus* was found in less than one-fourth of the roots examined. *Peniophora gigantea* apparently was very active in replacing *F. annosus* in these stump roots.

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1966. Research—the key to tomorrow. Disease research. The Unit 110: 33-35.

Disease research at the Southeastern Station is discussed. Special emphasis is placed on current status and approaches to research on soil-borne diseases, fusiform rust, annosus root rot, air pollution.

———— and Haasis, F. A.

1964. The perfect stage of *Cercospora magnoliae*. Mycologia 56: 53-57.

A report and description of *Mycosphaerella milleri*, the perfect stage of *Cercospora magnoliae* which causes a common leaf spot of magnolia in the Southeast.

———— and Jorgensen, E.

1967. *Fomes annosus* root rot. *Fomes annosus* (Fr.) Cke., pp. 48-52. *In* A. G. Davidson and R. M. Prentice [ed.], Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. Dep. Forest. & Rural Develop., Canada, Pub. 1180.

Contribution on forest pest problems by the Working Group on Forest Insects and Diseases, North American Forestry Commission, FAO.

Hoekstra, P. E.

1965. A simple, inexpensive pollen trap. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-40, 3 pp.

Trap employing clear cellulose tape proved superior to vaseline-coated glass slides for pollen trapping and identification.

Hook, D. D., and Brown, C. L.
1967. Lactic acid production in the roots of *Nyssa sylvatica* var. *biflora* (Walt.) Sarg. (Abstr.) Assoc. South. Agr. Workers Proc. 1967: 280-281.

Presents hypothesis that lactic acid fermentation functions as an alternate respiratory pathway in swamp tupelo roots; i.e., under high oxygen tensions, pyruvic acid is primarily reduced to lactic acid, and under low oxygen tensions, pyruvic acid is primarily oxidized through the normal oxidative pathway. This physiological duplicity appears to be one means by which swamp tupelo is able to thrive with its roots under water for prolonged periods of time.

——— **LeGrande, W. P., and Langdon, O. G.**
1967. Stump sprouts on water tupelo. South. Lumberman 215(2680): 111-112.

Stump-sprouting characteristics of water tupelo 30 years after logging are illustrated pictorially and tabularly. Stump-sprout growth in diameter and height are compared to that of trees of seed origin of the same age. Implications of stump-sprouting are discussed in relation to tupelo regeneration.

——— **and Stubbs, Jack**
1965. Selective cutting and reproduction of cherrybark and Shumard oaks. J. Forest. 63: 927-929.

Seven years after a selection cut, only 3 percent of the cherrybark and Shumard oak seedlings were more than 12 inches tall. Distance from sample trees, diameter of sample trees, diameter of sample trees squared, and length of opening transects had a significant effect upon number of the seedlings. Abundant reproduction is established but not developing satisfactorily, and larger openings appear necessary if these species are to be managed under the selection method.

——— **and Stubbs, Jack**
1967. An observation of understory growth retardation under three species of oaks. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-70, 7 pp.

Observations on a mixed bottomland hardwood site where seven species of seed trees were left to foster regeneration revealed that growth of understory vegetation was greatly retarded under a high percentage of three species of oak. Some plausible explanations of the causes and implications of this retardation are discussed.

——— **and Stubbs, Jack**
1967. Physiographic seed source variation in tupelo gums grown in various water regimes. Ninth South. Conf. Forest Tree Impr. Proc. 1967: 61-64.

One-year-old swamp tupelo and water tupelo seedlings were grown for one growing season in six artificially imposed water regimes with replications in 2 consecutive years. Height growth, leaf dry weight, total dry weight, stem form A (in flood zone), and stem form B (above flood zone) were measured. Results showed that height growth and dry weight varied significantly between some seed sources for each species. Both height growth and dry weight were lower in intermittent and continuous flooded treatments than under continuous surface saturated treatments. With the exception of one seed source from each species, dry weight production was less in the intermittent flooding than continuous flooding treatment. Stem form (butt swell) appeared to be related more to the presence of flooding than to seed source.

Hooper, R. G. III

1968. Wild turkey on the rebound. Forest Farmer 27(9): 8-9.

Deforestation and illegal hunting extirpated the wild turkey from much of the South. Reforestation and stocking with live-trapped wild birds have reestablished the turkey in many areas.

Hough, W. A.

1965. Palmetto and gallberry regrowth following a winter prescribed burn. Ga. Forest Res. Counc. Res. Pap. 31, 5 pp.

Vegetative recovery of palmetto and gallberry was followed for a year after a winter hazard reduction burn. Rate of regrowth of the two species was very different and was attributed to differences in growth characteristics. Palmetto vegetative weight regrew to 55 percent and gallberry to 70 percent of the before-burning dry weight.

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1968. Carbohydrate reserves of saw-palmetto: seasonal variation and effects of burning. Forest Sci. 14: 399-405.

Carbohydrate reserves of saw-palmetto were measured periodically in burned and unburned plants. In rhizomes of unburned plants, starch was the principal storage carbohydrate, with sucrose, glucose, and fructose present at much lower concentrations. A seasonal cycle in starch showed a high of 37 percent in winter and a low of 27 percent in summer. Total sugar content was about 4 percent, without seasonal changes.

Following removal of the fronds by fire, starch content of the rhizome dropped to 1 to 2 percent, whereas sugar content increased to 12 to 14 percent. Total carbohydrate content was lowest in October after the winter burn. Accumulation, mainly as starch, started after October and continued through the winter months. Recovery after a single burn occurred within 4 years. Moisture content of rhizomes increased greatly following burning.

Saw-palmetto plants on an area reburned three successive summers after a winter burn still retained a carbohydrate content of 12 percent, slightly less than the lowest value following a single winter fire. It appears that timing of repeat fires may be most important if control of saw-palmetto is desired; heavy kill may never be accomplished by fire alone.

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1968. Fuel consumption and fire behavior of hazard reduction burns. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Pap. SE-36, 7 pp.

Fuel consumption and fire behavior of hazard reduction burns in slash-longleaf pine stands unburned for at least 10 years were evaluated under various environmental conditions during three winter seasons. Rate of spread of backfires was found to be inversely related to moisture content of the fresh litter layer and to relative humidity. Moisture content of the fresh litter was influenced by relative humidity and days since measurable rain and could be predicted from their values. Reduction of litter fuel and release of available fuel energy were found to be predictable from moisture content and dry weight values of the total litter layer.

Hughes, R. H.

1964. Some observations on germination of gallberry seed. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-17, 3 pp.

Seeds of *Ilex glabra* will germinate promptly, providing fresh seeds are cleaned and sown immediately after collection and germination conditions provide a moist, fungus-free medium at a temperature of 60° F. until the radicle begins to emerge. These rather exacting germinating conditions apparently impose serious limitations upon germination of gallberry seeds in the field.

Hughes, R. H.

1965. Animal damage, pp. 160-166. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Describes types of damage, effects on tree survival and growth, and recommends management to avoid or reduce damage.

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1965. Cultivation in pine plantations, pp. 287-291. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Cultivation of seedling and sapling trees for 1 to 4 years (or until the crowns close) reduces fire hazards, subdues competing vegetation, alleviates retardation from drought, and promotes rapid growth.

———

1966. Better management means more beef from wiregrass-pine ranges. J. Range Manage. 19: 41.

Cows on wiregrass range with a balanced feed program produced calves averaging 427 pounds at 8 months of age. Burned range, ample fall-winter feed, and some Brahman blood in cows were the key to increased beef production.

———

1967. Fire ecology of canebrakes. Fifth Annu. Tall Timbers Fire Ecol. Conf. Proc. 1966: 148-158.

This paper reviews response of cane (*Arundinaria tecta*) to fire and lack of fire. It is based upon experience in the canebrake country of North Carolina and upon the published reports that came out of a series of cooperative studies there. With periodic fire and carefully regulated grazing, cane is one of the most productive native grazing types in the United States.

——— **Hilmon, J. B., and Burton, G. W.**

1966. Improving forage on southern pine woodlands. Ninth Int. Grassland Congr. Proc. 1965: 1305-1307.

Abundant forage is produced on southern woodlands, but quality of native grasses is low. The grazing value of pineywoods rangeland may be improved by (1) burning, (2) site modification, such as chopping or disking and application of fertilizers, or (3) intensive culture, including land conversion and the introduction of improved forage species into intensively managed pine plantations. Results of recent research and some of the problems to be solved in each of these areas are discussed.

——— **and Knox, F. E.**

1964. Response of gallberry to seasonal burning. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-21, 3 pp.

Gallberry (*Ilex glabra*) was burned in January, April, June, August, or October. Numbers of stems increased following an initial burn and then remained fairly stable through two additional burns, regardless of the month of burning. The seasonal patterns of carbohydrate level in stems and rhizomes were not affected by season of burning. Measures other than fire are needed to obtain permanent control.

Hunt, D. L.

1967. Ninth-year performance of slash and loblolly pine nursery selections in Georgia. Ninth South. Conf. Forest Tree Impr. Proc. 1967: 92-94.

The selection of outstanding loblolly and slash pine seedlings in the nursery is a feasible means of locating trees potentially outstanding in vigor for use in future breeding work.

Hutchinson, J. G., and Bramlett, D. L.
1964. Frost damage to shortleaf pine flowers. J. Forest. 62: 343.

Flowers showed evidence of damage 5 days after a spring fros and were completely necrotic after 11 days. Female flowers are apparently most sensitive to frost damage during the receptive stage

Ike, A. F., Jr.
1966. Sycamore produces viable seed after six years. Southeast. Fores Exp. Sta., U. S. Forest Serv. Res. Note SE-62, 2 pp.

Three of five 1-year-old, nursery-grown sycamore seedlings planted as shade trees in Athens, Georgia, produced viable seed 5 years after transplanting. These observations suggest that selected sycamore trees can be stimulated to produce seed at early ages.

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1967. Type-site relationships in the Piedmont. 1966 Symp. Hardwoods of the Piedmont & Coastal Plain Proc., Ga. Forest Res. Counc., Macon, Ga., pp. 12-15.

As competition for land becomes increasingly severe, it becomes more and more important for foresters to effectively match site with species. In the Piedmont of the southeastern states, residual upland sites are best suited to pine. Only the coves and bottomlands are truly suitable for management of high quality hardwoods. The best cove sites, in which hardwood management might be expected to pay off, are the uneroded, moist lower slopes and the steep northeast-facing slopes with deep soils. Soil texture and drainage class are probably the two best diagnostic soil properties for site evaluation in the bottomlands.

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1968. Symptoms of nutrient deficiency in yellow-poplar seedlings. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Note SE-94, 4 pp.

Visual symptoms are described for leaves of yellow-poplar seedlings supplied N, P, and K in varying concentrations ranging from minimal to excessive.

Probability of growth response to added N is high when tissue levels are below 2 percent; no response is likely when they exceed 3 percent.

——— **and Clutter, J. L.**
1968. The variability of forest soils of the Georgia Blue Ridge Mountains. Soil Sci. Soc. Amer. Proc. 32: 284-288.

Data collected from 123 forested plots in the Blue Ridge Mountains of northeast Georgia were used to (1) evaluate sample stratification criteria, (2) estimate the variability of physical and chemical properties of the soil, and (3) examine the efficiency of sampling schemes.

Sampling stratification seemed justified on the basis of soil series, but not on the basis of soil type. For similar soils, maximum efficiency in estimating means of soil series is obtained with one or two pits per plot. The number of plots (pedons) required for adequate precision is greater than the number customarily sampled for soil series characterization studies.

Sampling to estimate plot mean values in soil-site studies involves consideration of the variances of several properties to be estimated from one soil sample. The use of two to four pits (profiles) per plot in similar soils would seem to be adequate for most but not all commonly measured soil properties.

Ike, A. F., Jr., and Huppuch, C. D.

1968. Predicting tree height growth from soil and topographic site factors in the Georgia Blue Ridge Mountains. Ga. Forest Res. Counc. Res. Pap. 54, 11 pp.

Information obtained from a soil-site study of 10 commercial species growing in the northeast Georgia mountains has been summarized in tables showing the relationships between site index and various soil and topographic site characteristics. In addition, tables are given relating site index to soil series for three species.

Of the variables measured, topographic features were more closely related to site quality than were physical or chemical soil properties. Most reliable for use as predictors are those site features which influence climate and moisture supply, such as elevation, position on slope, aspect, and steepness of slope.

Jackson, L. W. R., and Hepting, G. H.

1964. Rough bark formation and food reserves in pine roots. Forest Sci. 10: 174-179.

Rough bark formation in pine is shown to result from starvation of the outer phloem. Diseases like littleleaf, in which root starvation is a feature, develop premature and excessive rough bark on the roots.

James, G. A.

1966. Instructions for using traffic counters to estimate recreation visits and use on developed sites. USDA Forest Serv. Southeast. Forest Exp. Sta., 12 pp.

A simple, inexpensive, and reliable technique is described for using pneumatic traffic counters to obtain estimates of recreation visits and use at unattended recreation sites.

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1967. Recreation use estimation on Forest Service lands in the United States. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-79, 8 pp.

Development and field-testing of sampling techniques for estimating use on Forest Service recreation sites and areas have been in progress for about 5 years. Several methods have been recommended for general use. Other sampling models are in various stages of development and testing. The paper describes several of the more promising sampling techniques.

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1968. The future of hunting in the South Atlantic States. Univ. Mo. Sch. Forest., Mo. Log 21: 31-33.

The lure of hunting beckoned almost 2 million persons, 12 years or older, to field, forest, and wetland in the South Atlantic States during 1965. There is every indication that hunting will likely remain near the high 1965 level through the year 2000. But great pressures—urban sprawl, road construction, harmful agricultural and grazing practices, to name a few—threaten our Nation's valuable wildlife resources. Concerted and continuing effort by private groups, and by Federal, State, and municipal governments, is vitally needed to protect this resource from indiscriminate abuse.

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1968. Pilot test of sampling procedures for estimating recreation use on winter-sports sites. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Pap. SE-42, 8 pp.

A sampling technique for estimating winter recreation use was pilot tested on the Brighton Winter-Sports Site in Utah during 1966-67. Reliable estimates of use, by activity, were obtained at low cost. The paper describes procedures used, and includes recommendations for future sampling efforts.

James, G. A., and Cottrell, R. L.
1968. To cut or not to cut. J. Forest. 66: 57-59.

Three closely related research studies were installed on Indian Boundary Campground, Tellico Ranger District, Cherokee National Forest, in 1964. Two are designed to study biological and ecological relationships, and include the following objectives: (1) To determine relations between the timing and intensity of overstory density reduction on the response of understory vegetation, and (2) to determine which native and introduced species of understory vegetation are best suited for planting on developed recreation sites. The third study is designed to determine camper reaction to the cutting treatments installed.

——— **and Harper, R. A.**
1965. Recreation use of the Ocala National Forest in Florida. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-18, 28 pp.

Mass and dispersed types of recreation use were estimated during a 1-year period by simultaneously using double-sampling and stratified random sampling techniques. The Ocala National Forest received almost 1½ million visitors, and 29 million visitor hours of total use, during the sampling period.

——— **and Harper, R. A.**
1967. How much and what kind? A close look at outdoor recreation on the Ocala National Forest. Fla. Wildlife 21(2): 18-19.

Two sampling methods were used over a 1-year period to estimate number of visitors and hours of recreation use by activity on the Ocala National Forest in Florida. Almost 1½ million persons visited the forest during the 12-month period, and they engaged in approximately 29 million hours of varied activities. Eighty-four percent of this total use was devoted to some form of recreation, 11 percent to residential use, and about 5 percent to commercial use.

——— **and Henley, R. K.**
1968. Sampling procedures for estimating mass and dispersed types of recreation use on large areas. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-31, 15 pp.

A pilot test was successfully employed during summer 1966 to estimate mass and dispersed types of recreation use on the Pacific District, Eldorado National Forest in California. Use was sampled using a stratified random-sampling technique which incorporated road checkpoints at which exiting recreationists were interviewed to obtain information concerning length of stay and recreational activities pursued. The Pacific District received almost 195,000 visitor-days of recreation use during the 101-day sampling.

——— **Johnson, F. M., and Barick, F. B.**
1964. A key to better hunting—forest roads and trails. Wildlife in N. C. 28(3): 14-15.

Analysis of the plotted locations of over 4,100 deer kills, collected during four hunting seasons on 14 wildlife management areas in the Piedmont and mountains of North Carolina, indicates that the number and location of roads and trails have an important relation to deer kill, but are not the only factors controlling hunter distribution.

Most deer were harvested close to roads or trails, but important differences were found in the use of forest access between the Piedmont and mountain areas. In the mountains of western North Carolina successful hunters made use of all portions of the forest, and their kills apparently were uniformly distributed. Hunters in the Piedmont apparently stayed close to access and did not generally penetrate into more remote sections.

Perhaps the most important finding of the study was that successful hunters made about equal use of roads and trails, and that trails received heavy use in dispersing hunters away from roads.

James, G. A., Johnson, F. M., and Barick, F. B.
1964. Relations between hunter access and deer kill in North Carolina. Twenty-Ninth N. Amer. Wildlife & Natur. Resources Conf. Trans. 1964: 454-463.

Analysis of over 4,000 deer-kill locations on 13 wildlife management areas in western North Carolina during four hunting seasons, 1959 to 1962, provided information on the use of roads and trails by successful deer hunters. Roads and trails apparently served about equally in distributing successful hunting pressure.

——— and Rich, J. L.
1966. Estimating recreation use on a complex of developed sites. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-64, 8 pp.

Recreation use was estimated on a complex of eight developed recreation sites in North Carolina during a 1-year period, using a regression model sampling technique. The technique produced acceptable use estimates on all sites and provided an important tool for reducing sampling costs. Equations based on traffic-count records from one key location can be used to estimate total and component recreation use on all sites.

——— and Taylor, G. D.
1967. Recreation use estimation in the United States and Canada. XIV. IUFRO-Congr. Proc. Vol. VII (Sect. 26) Munich, 1967: 14-29.

Burgeoning recreation use of public lands in the United States and Canada during the past few years has placed great pressures on resource managers. The need to look ahead at least 5 years in park and recreation area operations requires considerable knowledge about the recreation user and the amount and kind of pressures the lands are currently receiving and are likely to receive in the future.

Development and field-testing of sampling techniques have been in progress in the United States and Canada for approximately 6 years, and several methods have been recommended for general use. The paper briefly describes several of the more promising sampling techniques and indicates needs and guidelines for further productive work.

——— and Tyre, G. L.
1967. Use of water-meter records to estimate recreation visits and use on developed sites. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-73, 3 pp.

Pilot tests were conducted on two Forest Service developed sites during 1966 to determine relationships between water use and hours of recreation use by activity. Linear regression analyses revealed that volume of water used on the test sites was highly correlated with recreation use.

arrett, T. W.
1964. Depth of planting affects germination of white pine seed. J. Forest. 62: 502.

Survival of white pine seed planted in a screened area was significantly increased by planting below the ground surface. Maximum survival occurred when the seed were planted ½ to 1 inch below the surface. A test of planting dates showed no significant differences between survival of an April planting and a November planting.

ohansen, R. W.
1964. Effect of overstory on ground distribution of airdropped slurries. USDA Forest Serv. Fire Contr. Notes 25(2): 3-4, 15.

Drop-loads of at least 400 gallons are recommended for controlling fires in pine stands or hardwoods without leaf.

Johansen, R. W.
1967. A new approach to fireline construction. USDA Forest Serv. Fir Contr. Notes 28(1): 6-7.

A chemical line 30 feet wide is made with a tanker. Strip hea fires are then directed into the chemical line to quickly develop wide burned-out area.

——— 1967. A reproducible system for evaluating forest fire retardants. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-26, 9 pp

A method for testing the effectiveness of fire-retardant chemicals on woody fuels has been developed. The test involves the use of a preconstructed wood crib, one-half of which is treated with a fire retardant. The speed with which flames pass through the treated portion of the crib is plotted over the weight of dry chemical present. A regression curve is plotted for each chemical tha reflects treatment effectiveness in accordance with amount of chemical present. The most effective chemical has the steepest curve Of the chemicals tested, the best "effectiveness" ratings belong to ammonium sulfamate, ammonium phosphates (DAP, MAP, and 11-37-0), and ammonium sulfate in that order.

——— 1968. Fire control considerations in pine plantations. 7th Auburn Forest Forum Proc. 1968: 14-19.

The "checkerboard" system for fire protection is offered pine plantation owners. It involves arranging plantations so that older stands, fireproofed with hazard reduction burns, can be separated from younger, fire-susceptible stands by a network of access lanes and roads. A table shows how much land would be sacrificed to fire protection by checkering management areas into plantations of different sizes.

——— **and Cooper, R. W.**
1965. Aerial attacks on sand pine crown fires. South. Lumberman 211 (2732): 105-106.

Water and ammonium phosphate solutions were used successfully to stop head fires in the sand pine fuel type of central Florida.

——— **and Crow, G. L.**
1965. Liquid phosphate fire retardant concentrates. USDA Forest Serv. Fire Contr. Notes 26(2): 13.

Describes the mixing process, tells how solutions may be thickened and colored, and gives information on control of corrosion.

——— **and Shimmel, J. W.**
1967. Thickening retardants improves adhesion to tree crowns. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-84, 3 pp.

Several water solutions of different viscosities were released from an aerial tanker so that the effect of solution viscosity on interception of retardants by tree canopies could be studied. There was no apparent difference in interception between "wet" water and plain water. Viscous water, however, had greater adhesion to the tree canopies.

Johnson, F. M., Stubbs, Jack, and Klawitter, R. A.

1964. Rodent repellent value of Arasan-Endrin mixtures applied to acorns. J. Wildlife Manage. 28: 15-19.

A mixture of Arasan 75 and Endrin 50W was tried in two concentrations on acorns of Shumard oak (*Quercus shumardii*) and swamp chestnut oak (*Q. michauxii*) to determine its effectiveness in protecting acorns from damage by gray squirrels (*Sciurus carolinensis*) and cotton rats (*Sigmodon hispidus*). Treated and untreated acorns were exposed to 12 gray squirrels and 12 cotton rats in a series of cage tests. The repellent was effective against both squirrels and cotton rats when untreated acorns were also available. It was quite effective against cotton rats, but not against squirrels, when only treated acorns were available. In periods of abundant alternate food supplies, a direct seeding of treated acorns should produce a good stand, but this may not be true under adverse food conditions.

Jones, E. P., Jr.

1966. Performance of some non-native pines—ponderosa, pitch, pinyon, Scotch, and Corsican. USDA Forest Serv. Tree Planters' Notes 77: 4-5.

Yearly survival and height data for the six named species and varieties are briefly reported from observation plots in south central Georgia. Pitch pine (*Pinus rigida* Mill.) was the best performer at age 4, with 75 percent survival and 2.15 feet in average height. All trial species compare unfavorably with native slash (*P. elliottii* Engelm.) and longleaf (*P. palustris* Mill.) pine.

———

1966. Spot seeding—a method of direct seeding. USDA Forest Serv. Reg. 8, Direct-Seeding Workshops Proc. 1965: 85-87.

A few seed are dropped on spots from which the litter and grass have been chopped away. Simple and inexpensive tools can be used. The method is described as particularly suitable for old house sites and openings in the woods.

——— **and Bennett, F. A.**

1965. Ten years of timber management in the middle coastal plain of Georgia. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-16, 17 pp.

A 10-year progress report on a 2,300-acre demonstration forest in the middle coastal plain of Georgia. Numerous photos, tables, and graphs supplement the discussion of management practices, growth, costs, and returns. Also noted are changes in composition and structure of timber stands on this predominantly slash-longleaf forest.

Jones, LeRoy

1965. Water content and cost of stratified seed related. USDA Forest Serv. Tree Planters' Notes 71: 17.

A buyer purchasing stratified loblolly or slash pine seed should request a price adjustment if the original weight of the seedlot is not known. The charges for stratification and treating with repellents can be added to the original seed cost.

———

1966. Storing pine seed: what are best moisture and temperature conditions? Ga. Forest Res. Counc. Res. Pap. 42, 8 pp.

This 5-year study showed that seed of longleaf, slash, loblolly, shortleaf, and white pine can be stored successfully at temperatures of -5°, +5°, 15°, 25°, and 35° F., provided the moisture content of the seed is 12 percent or below. Recommended temperature for all species, except shortleaf, is 25° F.; shortleaf seed can be stored at 35° F.

Jones, LeRoy

1967. Effect of storage at various moisture contents and temperatures on seed germination of silk oak, Australian pine, and *Eucalyptus* spp. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-83, 4 pp.

Forest tree seed of the following three species can be stored satisfactorily for 2 years at either 20° or 38° F., provided that the moisture content is maintained within the limit of 10 percent or less for silk oak, 2.5 percent for *Eucalyptus* spp., and 6 to 16 percent for Australian pine.

——— **Barber, J. C., and Mabry, J. E., Jr.**

1964. Effect of methyl bromide fumigation on germination of longleaf, slash, and loblolly pine seed. J. Forest. 62: 737-739.

Longleaf, slash, and loblolly pine seed received methyl bromide fumigation experimentally at one-half normal dosage, normal dosage, and two times normal dosage. The seed had moisture contents of 5, 10, and 15 percent. Seed moisture content appeared to be more critical than the amount of fumigant used. Interactions between fumigation dosage and seed moisture content levels were significant. Study results showed that longleaf should have a 5 percent or lower moisture content before fumigation; moisture content of slash and loblolly should be 10 percent or lower. After 1 year's storage at 20° F., no further loss in viability was apparently caused by fumigation.

——— **and Havel, Kenneth**

1968. Effect of methyl bromide treatments on several species of conifer seed. J. Forest. 66: 858-860.

These results show that methyl bromide fumigation can injure or kill imported conifer seed if fumigation procedures and moisture content of seed are not adequately controlled. For the species tested, Scotch pine, mugo pine, Norway spruce, and white spruce, the seeds should be at a moisture content of less than 10 percent before fumigation. A 24-hour aeration period is also recommended.

——— **Massello, J. W., and Clifford, E. D.**

1967. Size and germination of white pine seed collected at weekly intervals from five trees. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-74, 6 pp.

Germination tests of six weekly collections of white pine seed from a seed production area in Michigan showed that:

(1) Germination of seed collected at different times differed significantly.

(2) Differences among trees were not significant.

(3) Seed from all collections had dormancy.

(4) Average number of seed per cone was 80, and an average of 420 cones produced 1 pound of seed.

Jorgensen, J. R.

1967. Fractionation of nitrogen in three forest soils. Soil Sci. Soc. Amer. Proc. 31: 707-708.

Soil nitrogen of forested Georgeville, Colfax, and Iredell soils from the North Carolina Piedmont was separated into six fractions. Amino acid N made up over 50 percent of soil N, while hydrolyzed NH_4^+ + amino sugar N was 22 percent of the total N. Proportions of exchangeable $NH_4^+ + NO_3^-$, insoluble humin N, and hydrolyzed NH_4^+ + amino sugar N differed with soil. The differences appeared to be related to base saturation and pH.

Jorgensen, R. N.

1968. Steam bending of hickory. USDA Forest Serv. Southeast. Forest Exp. Sta. Hickory Task Force Rep. 11, 12 pp.

Based on limited research and extensive industry practice, this report describes steam-bending procedures and material selection for all eight hickory species. The mechanical and physical properties of wood that affect bending are related to the equipment necessary for good bending. The better practices for seasoning, cutting-to-size, end-coating, steaming, setting, and drying are described.

Keetch, J. J.

1964. Developing a network of fire-danger stations. USDA Forest Serv. Fire Contr. Notes 25(4): 3.

Selected references on spacing of fire danger stations, and suggestions on minimum standards for spacing stations in developing a fire danger network.

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1966. Quality control in fire danger rating. USDA Forest Serv. Fire Contr. Notes 27(4): 11, 16.

Explains the role of quality control in fire danger rating in maintaining uniform standards of measurement and effective methods of data verification. Describes a series of six checkpoints including site, installation, maintenance, operation, recording, and computation. The technical difficulty and level of responsibility is discussed for each checkpoint.

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1967. The relation of spread index to fire business in Connecticut. USDA Forest Serv. Fire Contr. Notes 28(2): 13-15.

Examines the relation between spread index and fire activity in the 1964 season, according to the distribution of number of fires and acres burned by size class.

——— **and Byram, G. M.**

1968. A drought index for forest fire control. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Pap. SE-38, 32 pp.

A method is discussed whereby fire control managers in forested areas of the United States can estimate the degree of drought. A drought index based on 8 inches of available moisture is presented, and the procedures for computing the drought index are outlined. For purposes of illustration, drought development in five widely separated areas of the United States is depicted graphically.

An appendix develops the essential physical concepts and the general theory for a method of drought estimation that should operate throughout a wide range of climatic and rainfall conditions. A mathematical description of the overall process is included.

Klawitter, R. A.

1964. Water tupelos like it wet. South. Lumberman 209(2609): 108-109.

Along the lower Santee River in South Carolina, taller water tupelos occurred where soil and other site conditions were characteristic of poor drainage and long periods of wetness. Water levels play an important role in the growth, development and, probably, distribution of water tupelo in bottomland swamps.

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1965. Woodland drainage in the Southeast. J. Soil & Water Conserv. 20 (4): 181-182.

A brief account of woodland drainage practices in the Southeast and their use to alter various wet forest sites is given in this paper.

Klawitter, R. A.

1966. Diameter growth of mature loblolly pine unaffected by under-story control. South. Lumberman 213(2656): 154-155.

Comparison of diameter growth of 60-year-old loblolly pine on plots where the under-story had been eradicated by prescribed summer fires with growth on those where the under-story was untreated did not show a meaningful difference. Adequate growing season rainfall and advanced age of the trees could explain the results.

——— 1966. Early response of pole-sized slash pine to drainage. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-63, 2 pp.

Early results from a drainage study on the Appalachicola National Forest indicate height growth of pole-sized slash pine may improve considerably within a few days after sandy, wet pine flats are ditched.

——— 1967. Drainage. 1966 Symp. Hardwoods of the Piedmont & Coastal Plain Proc., Ga. Forest Res. Counc., Macon, Ga., pp. 16-17.

Considerable acreage of wet hardwood land in the Southeastern coastal plain has been drained purposefully for conversion to pine and inadvertently by upland forest drainage activities and in flood control programs. The question is whether or not such drainage represents a real threat to the productivity of wet hardwood lands for hardwoods. Research knowledge available and under development by the Project and elsewhere was used to demonstrate that drainage of wet hardwood lands is a serious problem. Foresters, landowners, engineers, and scientists were alerted to the kinds of knowledge needed to enable forest water control to proceed on a scientific basis on wet hardwood lands.

——— 1967. Water management in coastal plain woodlands. South. Lumberman 215(2680): 175-177.

Water management is a reality in many acres of wet woodlands in the coastal plain. Man has shown he can shape wetland forest environments to meet his future needs for any one of several natural resources by prescribed changes in water regimes, soil properties, and forest vegetation. However, since man's needs change with time, perhaps the measures we apply to wetland forests should be sufficiently controlled and well enough understood to enable us to change from the production of one forest resource to another as the future demands.

——— 1968. Soils information used and needed for woodland production: research findings—organic soils. South. Reg. Tech. Work-Planning Conf. Coop. Soil Survey Proc., Clemson Univ., Clemson, S. C.

Large acreages of organic soils in the South are available for woodland production, but landowners need information about these soils to aid in site selection. Criteria that should be included in soil surveys of organic soils in the future to guide woodland owners include: botanical origin, stratigraphy, depth, degree of decomposition, wood content, acidity, water sources, and water conductivity. In addition, information on the subsoil material, natural vegetation, and fertility is needed.

——— **and Young, C. E., Jr.**

1965. Forest drainage research in the coastal plain. J. Irrig. & Drainage Div., ASCE, Vol. 91, No. IR3, Proc. Pap. 4456, pp. 1-7.

Results are based on a study in northwest Florida and a survey in coastal North Carolina. Soil productivity increases were assessed in terms of pine tree height and volume growth.

Knight, H. A.

1964. Pulpwood prices in the Southeast, 1963. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-28, 2 pp.

Average prices paid for rough pulpwood at delivery points, 1957 through 1963, and current average prices paid for chips.

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1968. A preview of "South Carolina's Timber, 1968." Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Note SE-96, 4 pp.

A fourth survey of South Carolina's timber resource shows that over the past 10 years the area of commercial forest land has increased by 4 percent and the volume of growing-stock timber by 19 percent. In 1967, net growth of growing stock exceeded removals by over 200 million cubic feet, or 48 percent.

——— **and McClure, J. P.**

1966. North Carolina's timber. Southeast. Forest Exp. Sta., U. S. Forest Serv. Resource Bull. SE-5, 47 pp.

Area of commercial forest land in North Carolina has increased by almost 2 million acres since the first Forest Survey in 1938. Over this same period, volume of timber increased by 3.7 billion cubic feet—a 25 percent gain. Currently, timber growth is exceeding timber cut by over 20 percent each year.

——— **and McClure, J. P.**

1967. Virginia's timber, 1966. Southeast. Forest Exp. Sta., U. S. Forest Serv. Resource Bull. SE-8, 47 pp.

Area of commercial forest land in Virginia has increased from 15.4 to 15.8 million acres since the second Forest Survey in 1957. Over this same period, hardwoods have either replaced or partially replaced the pines on about 700,000 acres. Volume of hardwood timber has increased from 9.5 to 10.5 billion cubic feet, a gain of 10 percent. Volume of softwood timber, mainly pine, has dropped from over 4.4 to less than 4.3 billion cubic feet, a loss of 3 percent. In 1965, estimated removal of softwood exceeded net growth by 15 percent; net growth of hardwood exceeded removal by 38 percent.

——— **and Nichols, A. C.**

1964. Southern pulpwood production, 1963. South. and Southeast. Forest Exp. Stas., U. S. Forest Serv. Resource Bull. SE-3, 26 pp.

Round pulpwood production by county, and wood residue used for pulp manufacture by state and type of residue; also, presents a 10-year review of trends in the southern pulpwood industry.

——— **and Nichols, A. C.**

1964. Veneer log production and consumption in the Southeast, 1963. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-37, 4 pp.

Production and consumption of veneer logs by species and state; also, a directory of the veneer plants located in the Southeast.

Koenigs, J. W.

1968. Control of fusiform rust on southern pines in nurseries. U. S. Dep. Agr. Plant Dis. Rep. 52: 597-599.

In a slide germination test ferbam prevented germination of sporidia of *Cronartium fusiforme* at 1/6 the concentration usually applied in the nursery. With the use of a new method, telia germinated and sporidia abjected and germinated in 4.8-6.0 hours, or about 1/3 to 1/2 the time previously reported. Seedlings added up to 0.5 inch of new terminal growth in 4 days. Ferbam seems to be an effective protectant, and occasional lapses in rust control with the current control recommendations apparently originate from failure to recognize the shorter duration of stages of the life cycle and the rapidity of seedling growth.

Koenigs, J. W.

1968. Survival and growth of *Fomes annosus* at high concentrations of borax. (Abstr.) Phytopathology 58: 1056.

F. annosus grew on agar and in liquid malt-yeast extract media containing 1,530 and 6,100 p.p.m. borax, respectively. These concentrations are 15 and 60 times greater than fungitoxic levels reported previously. Conidia germinated and grew on an agar medium with 380 p.p.m. borax but not 1,530 p.p.m. To further test sensitivity of the fungus to borax, 6-mm. discs from agar cultures, pure-mycelial fragments, and conidia were each shaken for 2, 4, and 8 days in 380, 1,530, 6,100, 24,400, and 97,600 p.p.m. borax in sterile, distilled water and then rinsed and plated. The fungus grew from (i) discs and mycelial fragments exposed to 6,100 p.p.m. for 8 days and 24,400 p.p.m. for 2 days, (ii) a single disc of one isolate exposed to 24,400 p.p.m. for 4 days, (iii) mycelial fragments of the other two isolates (single replicates) exposed to 24,400 p.p.m. for 8 days, (iv) conidia of one isolate exposed to 1,530 p.p.m. for 8 days, and (v) single conidia of another isolate exposed to 6,100 p.p.m. for 4 days and 24,400 p.p.m. for 2 days. Exposure of mycelial fragments to high concentrations of borax may have produced stable, nonsporulating forms of *F. annosus*. These results and others suggest that the effectiveness of borax as a stump protectant in control of *F. annosus* is not solely due to sensitivity of the fungus to the chemical.

Kormanik, P. P.

1966. Predicting site index for Virginia, loblolly, and shortleaf pine in the Virginia Piedmont. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-20, 14 pp.

Higher site indices for Virginia and shortleaf pines were found in the northern Piedmont, whereas the loblolly pine site index was higher in the southern Piedmont. Site index of shortleaf pine was related to texture and thickness of the B2 horizon; for Virginia pine, to the texture of the A2 horizon; and for loblolly pine, to the thickness and clay content of the B2 horizon and soil drainage class.

——— **and Brown, C. L.**

1964. Origin of secondary dormant buds in sweetgum. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-36, 4 pp.

Most dormant trace buds in deciduous trees are laid down by apical meristems on newly elongating shoots. These supernumerary buds, arising within the basal scales of axillary buds, remain visible for several years, but are slowly embedded in the periderm. Observations indicate that in sweetgum the majority of these buds branch during succeeding years while still covered by the periderm and give rise to numerous additional buds. These are commonly referred to as "secondary dormant trace buds." Apparently most of these buds are of scale origin.

——— **and Brown, C. L.**

1967. Adventitious buds on mature trees. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-82, 7 pp.

Adventitious buds can be initiated on older trees of different species and can give rise to epicormic branches. On yellow-poplar, sweetgum, green ash, and red maple, the epicormic branches originating from adventitious buds are uncommon and die soon after formation. Unlike the branches from suppressed trace buds, those from adventitious buds may be of little consequence in lumber defects in these four species. On water and white oak, however, 30 percent or more of the epicormic branches appeared to be of adventitious bud origin. On these two species, the adventitious buds may originate from at least three different sources and give rise to long-lived epicormic branches which can be a significant factor in lumber degrade.

Kormanik, P. P., and Brown, C. L.

1967. Epicormic branching and sprouting in hardwoods: a new look at an old problem. 1966 Symp. Hardwoods of the Piedmont & Coastal Plain Proc., Ga. Forest Res. Counc., Macon, Ga., pp. 21-24.

The ontogeny and physiological controls of suppressed buds in hardwood species are not understood. Yet, epicormic branches which develop from them are responsible for more degrade in hardwood lumber than any other single agent. Although in most species epicormic branches originate primarily from suppressed buds which have, in turn, been initiated by the apical meristem, they may also arise from adventitious buds. Recently, we found that adventitious buds were responsible for up to 30 percent of the epicormic branches on some white and water oaks. Species such as aspen, white poplar, and sweetgum readily produce suckers from roots. These suckers originate from buds of adventitious origin. These buds appear to develop as a result of injury to the root or because of some other stimulus. In sweetgum, buds develop during the first year's growth from either the primary pericycle tissue or the cambium. Many become suppressed and grow within the periderm of the root as diameter increases.

——— **and Brown, C. L.**

1967. Epicormic branching: a real problem in plus tree selection. Ninth South. Conf. Forest Tree Impr. Proc. 1967: 69-74.

Selection of trees that are genetically superior in their ability to inhibit suppressed bud eruption and thus remain free of epicormic branches is a pressing silvicultural problem. One of the drawbacks in our selection programs is that we have not recognized that selection made at one point in time assumes a status quo condition in both suppressed bud and epicormic branch development. In nature, however, the internal physiological processes of the tree, influenced by environmental factors, are constantly undergoing changes. Meaningful selections can be anticipated only when we are able to determine what growth substances inhibit suppressed bud development and how environmental conditions affect them.

——— **and Brown, C. L.**

1967. Root buds and the development of root suckers in sweetgum. Forest Sci. 13: 338-345.

Sweetgum (*Liquidambar styraciflua* L.) reproduces prolifically from root suckers in the Georgia Piedmont. Histological observations of lateral root segments without visible buds or suckers reveal numerous suppressed buds embedded in the periderm with vascular traces extending either to the stele of the primary root or to a point of previous root injury. Clusters of adventitious buds are often found embedded in the periderm in swellings associated with aborted lateral roots, and the vascular traces of these buds become continuous with those of the previously formed lateral roots. The exposure of lateral roots to light resulted in the immediate release of numerous suppressed buds all along their surface. Complete girdling of exposed lateral roots had a similar but more restricted effect. The released buds were always concentrated on the side of the girdle away from the parent tree, indicating that some type of inhibition was removed. Histological observations of released buds and their later formed root suckers confirmed the suckers' origin from previously formed suppressed buds.

——— **and Porterfield, E. J.**

1966. Rooting yellow-poplar cuttings. Forest Farmer 26 (2) : 24, 41-42.

Epicormic branches can be induced on yellow-poplar to furnish a large number of cuttings for vegetative propagation. Selected trees should be partially girdled 4 to 6 weeks before the buds begin to swell. The resulting epicormic branches are then cut from the tree and placed in a mist bed to develop roots.

Kormanik, P. P., Steinbeck, Klaus, and Brown, C. L.

1966. A new variety of sweetgum. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-55, 2 pp.

A dwarf variety of sweetgum near Athens, Georgia, is about 10 feet tall and has been reproduced vegetatively.

Kraus, J. F.

1965. Conversion of oleoresin yields from short-season microchipping to full-season yields from standard chipping. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-48, 4 pp.

Reasonably good correlations between oleoresin yields obtained from short-season microchipping and yields from full-season standard chipping permitted the development of conversion factors for use in the comparison of clones or progenies of slash pine.

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1967. A study of racial variation in loblolly pine in Georgia—tenth-year results. Ninth South. Conf. Forest Tree Impr. Proc. 1967: 78-85.

For a smaller but more intensively sampled area, the tenth-year results of the Georgia Loblolly Racial Variation Study largely substantiate those obtained from the Southwide Pine Seed Source Study. The general conclusions which apply are similar:

1. Racial variation in loblolly pine in Georgia is clinal, with growth rate decreasing with increasing distance from the coast.
2. Within Georgia, trees from provinces south of the planting province grew best in all but the Georgia flatwoods.
3. Trees from a western source (Arkansas) had the lowest percentage of rust infection.

——— **and Squillace, A. E.**

1964. Inheritance of yellow oleoresin and virescent foliage in slash pine. Silvae Genet. 13: 114-116.

Selfing and outcrossing of a tree producing yellow oleoresin showed that this trait was inherited as a homozygous recessive, but the number of genes involved has yet to be determined. Controlled breeding on two other trees having virescent foliage showed that this trait was also inherited but the exact mode of inheritance could not be determined.

——— **and Squillace, A. E.**

1964. Selfing vs. outcrossing under artificial conditions in *Pinus elliottii* Engelm. Silvae Genet. 13: 72-76.

Under artificial test conditions, the degree of self-fertility, as expressed by the numbers of seedlings produced per cone varied greatly among seven trees but averaged about 18 percent of cross-fertility. When using mixtures of self and outcross pollens on three mother trees having gene markers (yellow oleoresin or virescent foliage), the degree of selfing was not greatly different from expectation based on their respective self-fertilities. The results suggested that the degree of selfing in seed orchards will depend greatly on the number of clones used and on the degree of self-fertility of the clones. A slash pine orchard containing at least 20 clones will probably produce only a slightly greater proportion of selfs than that which occurs in natural stands.

Kuhlman, E. G.

1966. Recovery of *Fomes annosus* spores from soil. (Abstr.) Phytopathology 56: 885.

Using the dilution plate technique and a selective agar medium, spores of *Fomes annosus* were recovered from forest soils. *F. annosus* conidia were recovered 8 months after they had been added to the soil. Because spores remain viable in soil for prolonged periods of time, the possibilities for direct root invasion are extended far beyond the aerial life of the spores.

Kuhlman, E. G.

1968. Survival of *Fomes annosus* in the presence of competing fungi in loblolly pine roots. (Abstr.) Phytopathology 58: 729.

Long-term survival of *F. annosus* results from its active decomposition of woody material in the soil. Root-bark appears to bar the entry of saprophytic competitors from the soil. To determine if *F. annosus* is replaced through bark openings by soil fungi under field conditions, a 2x6-inch bark section was removed from each of 300 loblolly pine stump roots. Samples of the underlying wood were cultured to identify the original mycoflora. Thirty-eight percent of the roots were infected with *F. annosus*. After 1, 2, 5, and 12 months, 75 roots were cultured 0.5 inch beneath the bark opening, 6 inches distally from the opening, and from the bark. During the four sample periods, there was no significant decrease in *F. annosus* beneath the opening (26, 41, 42, and 27 percent) as contrasted to the wood 6 inches away (39, 42, 46, and 37 percent). *Trichoderma* spp. were the most frequently isolated fungi, and they sometimes masked the presence of *F. annosus*. Various Mucorales and bacteria were isolated from both bark and wood and may be important in the final breakdown of these substrates. *Peniophora gigantea*, the best known competitor of *F. annosus*, was present in 10 percent of the roots. *F. annosus* was also recovered from the bark of 30 percent of the roots, indicating that it competes well with both bark- and soil-inhabiting fungi.

——— **and Hendrix, F. F., Jr.**

1964. Infection, growth rate, and competitive ability of *Fomes annosus* in inoculated *Pinus echinata* stumps. Phytopathology 54: 556-561.

Infection and development of *Fomes annosus* was studied on artificially inoculated shortleaf pine stumps. Infection of uninoculated stumps rose sharply between 3 and 6 months, and then decreased between 6 and 9 months. Basidiospores of *F. annosus* were most effective in producing infection, and *Peniophora gigantea* was the most effective competitor in replacing *F. annosus*.

——— **and Hendrix, F. F., Jr.**

1965. Direct recovery of *Phytophthora cinnamomi* from field soil. (Abstr.) Phytopathology 55: 500. Also in (Abstr.) Assoc. South. Agr. Workers Proc. 1965: 228.

Soil from an *Abies fraseri* nursery naturally infested with *Phytophthora cinnamomi* was sprinkled on the surface of a modified Kerr's medium. *P. cinnamomi* grew into the medium from the soil crumbs and could be readily distinguished. Colonies originated from chlamydospores which were frequently embedded in decomposing organic matter.

LaFarge, Timothy, and Kraus, J. F.

1967. Fifth-year results of a slash pine polycross progeny test in Georgia. Ninth South. Conf. Forest Tree Impr. Proc. 1967: 86-91.

Of 35 half-sib progenies, eight were superior to the best control or the mean of all progenies, whichever ranked highest, for total height, the crown width/total height ratio, and the average number of cankers per tree of *Cronartium fusiforme* Hedgc. and Hunt ex Cumm. Conversely, six families were relatively inferior for these traits.

Lamb, R. C., and Pharo, J. A.

1967. Standardizing meteorological instrument testing. Amer. Meteorol. Soc. Bull. 48: 707-708.

There presently exists a need for standardized testing techniques for meteorological instrument sensors and systems. It is suggested that representatives of the American Meteorological Society, the National Bureau of Standards, and the meteorological equipment manufacturers meet to determine these standard tests.

Lane, J. M.

1967. First-year results: 366 barrels of gum from 8 monthly paste streaks. Nav. Stores Rev. 77(2): 4, 8. Also, with title 366 Barrels of gum from 8 monthly paste streaks, in AT-FA J. 29(9): 12-14.

Eight monthly streaks, one chipped every 28 days, and treated with 60 percent sulfuric acid paste, produced 280 barrels of gum per crop in slash pine and 366 barrels per crop in longleaf pine. Face heights from the monthly paste treatment were comparable to those produced by 16 biweekly streaks.

Langdon, O. G.

1965. The expanding role of research—public and private. Forest Farmer 24(8): 12-14, 28.

Research projects—often cooperatively sponsored by several agencies—are seeking answers for questions on direct seeding, forest genetics, weed tree control, hardwood management techniques, improved harvesting methods, soil manipulation and water management, insect and disease problems, and a myriad of other problems.

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1966. Plantation and direct-seeded stand management: a look at some future young stand management practices. USDA Forest Serv. Reg. 8, Direct-Seeding Workshops Proc. 1965: 137-140.

Discusses fertilization, control of competing vegetation, and control of young stand densities.

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1967. Comments on J. S. McKnight's paper: Application of uneven-aged silviculture to Southern hardwood forests. 1966 Symp. Hardwoods of the Piedmont & Coastal Plain Proc., Ga. Forest Res. Counc., Macon, Ga., pp. 64-65.

One of the first decisions that a landowner must make after deciding to place his hardwood forest under management is whether to regulate it under an even-aged or uneven-aged system. This article critiques a paper by a proponent of the uneven-aged system. One point of complete agreement is that single tree selection has no place in managing Southern hardwoods because most species are intolerant and will not regenerate in small openings. Uneven-aged management must therefore be based on group selection, and its proponents believe hardwoods should be managed in a patchwork of age classes. This patchwork is in part governed by conditions in the stand when management is applied. However, to base our future management on current stands is in reality committing ourselves to past mistakes made in the stands, and compounding them into the future.

——— **and DeBell, D. S.**

1967. Managing young hardwood stands in the Southeastern Coastal Plain: possibilities and research needs. 1966 Symp. Hardwoods of the Piedmont & Coastal Plain Proc., Ga. Forest Res. Counc., Macon, Ga., pp. 40-42.

What precommercial cultural operations are desirable and profitable for young hardwood stands in the Southeastern Coastal Plain? Sound answers to this question must be based on a knowledge of how young stands behave and how various treatments affect stand development and growth.

An intensive literature review drawing heavily on work in other regions suggests that precommercial thinning and pruning offer good possibilities as cultural practices for Southeastern Coastal Plain hardwoods. Available evidence indicates that these two practices in young even-aged stands may reduce rotation ages by as much as 40 percent and still produce large-sized, relatively high quality trees.

Langdon, O. G., Hatchell, G. E., and LeGrande, W. P.

1968. Can you top this loblolly pine growth? South. Lumberman 217 (2704): 197.

This paper reports the tremendous growth on a "wonder" plot in a nursery seedling selection study. Ten years after planting, loblolly pine in the plot averaged 47 feet tall and had a per-acre equivalent of 50 cords of merchantable wood. The largest tree on the plot was 8.9 inches d.b.h. and 49 feet tall; the tallest tree measured 50 feet tall, with a 7.1-inch diameter.

——— **and LeGrande, W. P.**

1965. Rodent depredation—a direct seeding problem. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-39, 3 pp.

This loblolly pine direct seeding study compared three sowing dates and four seed treatments in the South Carolina coastal plain. By the middle of April seed losses averaged 90 percent; none of the repellents proved effective.

Larson, J. S.

1967. Forests, wildlife, and habitat management—a critical examination of practice and need. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-30, 28 pp.

This paper reports on the nature and extent of forage clearing practices for game management in the Eastern United States, critically evaluates present knowledge of this practice, and presents a possible program for effective research.

Lawrence, J. D.

1968. Componentized residential construction—implications for wood used. South. Lumberman 217(2704): 221-223.

As a market for more than one-third of total annual lumber and plywood consumption, new residential construction warrants continuing attention and service by the wood products industry. Rising labor costs, decreasing availability of labor, and increases in construction activity promise growth opportunities for manufacturers of wood building component parts.

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1968. Cutting costs in rubber-tired skidder operations. Pulpwood Prod. & Saw Mill Logging 16(6): 14, 16.

Methods are suggested for cutting costs in logging operations in which rubber-tired skidders are used.

——— **and Dickerhoof, H. E.**

1968. Manufactured homes—evolution and market potential for the wood products industry. Forest Prod. J. 18(9): 57-59.

There are three methods of producing manufactured homes: traditional residential prefabrication, smaller pre-cut component parts, and completely factory-built homes. These methods are expected to offer growing markets for wood products for use in manufactured single- and multi-family housing, mobile homes, sectionalized houses, vacation houses, and others.

Lewis, C. E.

1964. Forage response to month of burning. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-35, 4 pp.

Ranges burned in March or May produced two and four times more forage 2 months after the fire than those burned in October, November, or January. *Aristida stricta* seeded profusely in the fall after a May burn, but produced few or no seed stalks when burned at other times of the year.

Lewis, C. E.

1965. Firebreak is versatile necessity. Fla. Cattleman & Livestock J. 2 (8): 38-39.

Open strips of improved pasture within woodlands serve as a barrier to fire, provide nutritious cattle-wildlife food, improve cattle distribution, encourage cattle use in adjacent timber stands, and serve as access roads. Pensacola bahia and big carpetgrass are effective firebreaks in south Florida.

Lewis, G. D.

1964. The log concentration yard—a market for multiple products. South. Lumberman 209(2609): 150-152.

Trends in cost-price relationships indicate that single-product marketing will not be profitable. Log concentration yards are one way of providing multiple-product markets which will permit loggers of the smaller timber tracts to remain in business and to make the transition from a single-product to a multiple-product stumpage buyer.

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1964. Logging cost appraisal: a progress report. Amer. Pulpwood Assoc. Tech. Pap. 63-62(7.6): 17-19.

Discusses logging cost appraisal study underway in the Southeast and compares the logging methods, crew sizes, and equipment used in the Piedmont and the Coastal Plain regions.

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1968. Needed: better management and supervision in logging operations. Forest Farmer 27(12): 6-8, 18.

Between 80 and 90 percent of the total time spent in producing saw logs and between 60 and 70 percent of that spent in pulpwood production on the small woodlands of the Southeast is spent in miscellaneous activities which cannot be related to wood production and which tend to disrupt the flow of logs. These activities require the greatest amounts of time in those logging operations where mechanical equipment is most commonly used. This indicates that the equipment being used by loggers cutting timber on the small Southeastern woodlands is not being properly utilized or is not suitable for the job.

As the small forest ownerships are a major source of commercial timber, logging operations must be profitable if this timber is to be harvested. Supervision of logging operations is required to insure that these miscellaneous activities are scheduled so that they can be done in a minimum of time without disrupting the entire logging operation while management is necessary to develop that crew-equipment combination which can harvest most efficiently.

——— **and Chappelle, D. E.**

1964. Farm woodland management cost and returns in the southern Piedmont of Virginia. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-15, 20 pp.

Comparison of results of projecting stands from 105 farm woodlands under conditions of stand improvement treatments and no treatments indicate that the more mature stands and the better stocked pine stands will not respond economically to treatment.

McAlister, R. H.

1966. Jet-type veneer dryers in the United States. Soc. Wood Sci. & Technol. SWST Log, April, pp. 1-2.

The effect of impinging the drying gas against the veneer surface is discussed in very general terms and compared to the parallel flow of drying gas used by conventional dryers. The advantages of jet drying—improved veneer quality, increased drying rate, and more efficient operation—are discussed.

McAlister, R. H.

1966. Urban rehabilitation—a challenge for wood. Forest Prod. J. 16(9): 58, 60, 62.

A description of slum buildings being renovated in a current New York City project. The unique features of this experiment, designed to rehabilitate a 5-story building in only 48 hours, are presented. The Forest Service development of a new wall paneling system and some industry-developed flooring systems are discussed briefly.

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1967. Jet veneer dryers: theory and operation. Woodworking Dig. 69 (6): 32-33.

The jet type veneer dryers are more efficient at removing moisture than conventional dryers. This difference is due entirely to the characteristics of the air flow at the surface of the veneer. These differences are discussed.

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1968. Pole framing — inexpensive solution to rural-housing construction. Amer. Soc. Agr. Eng., Econ. Housing Seminar Conf. Proc., Lincoln, Neb., 1967: 30-31, 37.

A construction system for rural or remote areas must be simple, require no unusual skills or equipment, and use materials readily available in the locality.

Pole framing is such a system. Cost figures for constructing low-cost pole-frame houses in a rural slum are presented based on the author's experience in South Carolina.

——— **and McDonald, J. K.**

1967. Fur-Lok panel system developed by U. S. Forest Service. Plywood & Panel 7(11): 22-25, 28.

Describes a new technique for attaching plywood paneling to walls. The system is based on the use of interlocking wedges that eliminate the need for nailing panels to furring strips. Developed for use in rehabilitation programs, where speed of installation is essential, the Fur-Lok system enabled two carpenters to panel an 8- by 17-foot room in a New York tenement in 3 hours and 23 minutes.

——— **and White, J. F.**

1967. Inexpensive thermocouple terminal board, connector. Forest Prod. J. 17(11): 44.

A method of making up an inexpensive thermocouple terminal board is presented along with a quick-coupling connector.

McAlpine, R. G.

1964. A method for producing clones of yellow-poplar. J. Forest. 62: 115-116.

Yellow-poplar is generally considered difficult to root, and even more difficult to establish successfully from rooted stem cuttings. Cuttings taken from stump sprouts of 7-year-old trees, however, rooted well under mist (63 to 85 percent), survived, and grew vigorously when transplanted. Rooted cuttings can be outplanted by clones, allowed to grow under intensive culture to a 2-inch root collar diameter, then cut and allowed to sprout. Cuttings multiplied from these sprouts may find value as clonal material to be used in studies dealing with site requirements, nutrition, and physiology where control of genetic variability is desirable.

McAlpine, R. G.

1965. Hardwood management in the Piedmont. Nat. Hardwood Ma 38(12): 38-39, 46.

A description of problems and research methods used to pla and grow native hardwoods successfully in the southeastern Pie mont. Shows the great possibilities for growing valuable hardwoo under scientific management on good sites. Topographic positi largely determines species-site relationships. Discusses need f site preparation, control of competition, and the benefits of fertiliz in sycamore culture. Describes successful propagation of yello poplar and sweetgum from cuttings.

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1966. Direct seeding of hardwoods in the Piedmont and mountain USDA Forest Serv. Reg. 8, Direct-Seeding Workshops Proc. 196 116-121.

Compares successes and failures of plantations and direct see ings in the South.

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1966. Vegetative propagation methods for hardwoods. Eighth Sout Conf. Forest Tree Impr. Proc. 1965: 14-20.

Latest techniques for grafting, layering, rooting of cuttings, an budding of root cuttings. The method chosen depends upon th objective, species, and age of tree to be propagated.

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1967. Managing young hardwood stands in the Piedmont. 1966 Sym Hardwoods of the Piedmont & Coastal Plain Proc., Ga. Forest Re Counc., Macon, Ga., pp. 43-44.

Describes a system for production of pulpwood grown on ver short rotations using machines to harvest rapidly growing sprou stems planted at close spacings. Pulping tests of such juvenile ma terial with leaves and bark included have been encouraging. Hig yields of fiber are predicted from coppice stands of sycamore an possibly other species such as sweetgum and boxelder.

——— **and Brown, C. L.**

1967. Outlook for fiber from short-term coppice rotations. Amer. Pulp wood Assoc. Tech. Pap. 66-49(2.11): 15-16, 18.

A new concept using an old silvicultural method proposes th mechanical harvesting of small, densely planted hardwoods at rota tions of from 1 to 5 years. Juvenile sycamores have been har vested and pulped to determine yield and paper quality. Thus far promising pulping tests have stimulated considerable speculatio upon the use of sycamore and possibly other hardwood species fo pulp production in a completely mechanized program.

——— **Brown, C. L., Herrick, A. M., and Ruark, H. E.**

1966. "Silage" sycamore. Forest Farmer 26(1): 6-7, 16.

A new concept in growing and harvesting pulpwood is presented Sycamore, planted at close spacings, may be harvested while relatively small, using an ordinary silage harvester. Successive harvests of resulting coppice can produce high yields of fiber a amazingly short rotations. Pulping tests of young sycamore trees with bark and leaves included have shown promise.

McClure, J. P.

1968. Predicting tree d.b.h. from stump measurements in the Southeast. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Note SE-99, 4 pp.

When a tree has been cut and only the stump remains as an indicator of tree size, a prediction equation can be used to estimate d.b.h. from stump measurements. An improved equation model was developed from stump measurement data collected by Forest Survey special study crews in North Carolina, Virginia, and South Carolina. Independent samples from Virginia and South Carolina were used to test equations derived from only the North Carolina sample, and a pooled sample of over 14,000 trees was used to compute equation coefficients for 53 southeastern tree species.

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1968. Sectional aluminum poles improve length measurements in standing trees. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Note SE-98, 4 pp.

The use of sectional aluminum poles to measure lengths in standing trees can reduce bias and improve measurement precision. The method has been tested extensively under a variety of field conditions by Forest Survey crews in the Southeast.

McDonald, J. K.

1967. Homes for hurricane country. Forests & People 17(3): 22-23, 30-31.

Wood, properly used, is the best and safest construction material for homes in hurricane country. This article presents 10 basic guidelines for the correct use of lumber, plywood, poles, timbers, and other wood products in the construction of hurricane-resistant homes. The construction practices advocated are based on the use of engineered fastenings to tie foundation, floor, walls, and roof together so that they function as a structurally integrated unit.

McGee, C. E.

1964. Species test in the sandhills. Forest Farmer 24(2): 10, 15.

Slash pine has been most widely planted in the sandhills because of its excellent early growth. The fifth-year results of comparison of 11 species planted on Americus and Lakeland deep sandy soils showed that loblolly pine and redcedar are two other promising species for these soils. The loblolly pine growth and survival have equaled slash pine, and redcedar shows promise as a source for Christmas trees.

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1966. Spring injection fails. South. Weed Conf. Proc. 19: 267-269.

Five species were injected with 2,4-D or 2,4,5-T amines at 3- or 5-inch spacings during July, January, or April. The best kill was obtained using 2,4,5-T during July; poorest overall results were from April injections, when less than 25 percent of stems treated were killed.

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1967. Growth and yield of hardwoods. 1966 Symp. Hardwoods of the Piedmont & Coastal Plain Proc., Ga. Forest Res. Counc., Macon, Ga., pp. 55-56.

Hardwood growth and yield information is urgently needed in the Southeast. The lack of money, manpower, suitable study areas, and technical ability severely limits the amount of information that will be forthcoming in the near future. Most of the southeastern hardwood forests occur in mixed stands and these stands present most of the technical difficulties. The complex nature of mixed stands and the great variation in individual tree quality within a stand require the development of new mensurational concepts for describing the growth and yield.

McGee, C. E.

1967. Regeneration in Southern Appalachian oak stands. Southeas Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-72, 6 pp.

Several stands of mixed oak were logged to various intensitie Desirable and undesirable regeneration followed the cutting regar less of intensity. However, development of the regeneration w related to the cutting intensity with the greatest height observe on plots completely clearcut.

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1968. Northern red oak seedling growth varies by light intensity ar seed source. Southeast. Forest Exp. Sta., U. S. Forest Serv. Re Note SE-90, 4 pp.

Northern red oak seedlings from each of three seed sources wer subjected for one growing season to one of four intensities light: full light, 70 percent light, 37 percent light, and 8 percen light. Seedlings grown in the open were taller than those grow in the shade and had more, generally heavier leaves. Height an leaf growth decreased as the amount of light reaching the plant decreased. Seed source, another important factor affecting growt was related to height growth, number of leaves per seedling, acor weight, and percent of multiple stems. Forty-one percent of th seedlings from one source had multiple stems, while only 11 percen and 4 percent of the seedlings from the other two sources ha multiple stems.

——— **and Clutter, J. L.**

1967. A study of site index for planted slash pine. J. Forest. 65: 491-49

To examine several of the assumptions on which the procedur for predicting height growth in relation to age is based, ste analyses of five trees in each of ten 25-year-old slash pine plantations in Chesterfield County, South Carolina, were studied. Th analyses indicated that the relationship of the logarithm of heigh and the reciprocal of age is essentially linear between ages 10 an 25. Analysis of all stands showed no correlation between th height reciprocal of age relationships and actual site indices. Ther was room for speculation, however, concerning bias; dropping on plantation from the computation caused a high degree of correlatio between actual site index and the slope of the height and ag regression.

——— **and Della-Bianca, Lino**

1967. Diameter distributions in natural yellow-poplar stands. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-25, 7 pp.

Diameter distributions obtained from 141 pure, natural, unthinned yellow-poplar stands in the Appalachian Mountains of Virginia North Carolina, and Georgia are presented in tables. The distributions are described in relation to stand age, site index, and total number of trees per acre, and are useful for stand management planning.

——— **and Scott, H. R.**

1965. Planting longleaf pine in the Carolina Sandhills. USDA Forest Serv. Tree Planters' Notes 70: 4-5.

Study reaffirms that dipping longleaf foliage improves survival, and that it is highly desirable from the growth standpoint to plant Grade 1 seedlings. Root pruning to 3 inches is not recommended, but more moderate pruning shows no significant reduction in survival or growth. Recommended practices are: allow at least 90 days between site preparation and planting, and plant after the period when hard freezes are expected.

McGee, C. E., and Smith, R. C.

1967. Undisturbed rhododendron thickets are not spreading. J. Forest. 65: 334-335.

A series of transects were installed in eight rhododendron thickets on Bent Creek Experimental Forest. Ring counts taken on stems along the transects showed that the thickets were essentially even-aged and that they were about the same age. Because no pattern in age could be observed, it was concluded that these undisturbed rhododendron thickets were not spreading. Therefore, control of these thickets can be delayed until the end of the timber rotation. At that time, control measures must be taken or the thickets will spread and cause serious competition to regeneration.

McGregor, W. H. D.

1965. Successful summer planting of slash pine. J. Forest. 63: 208-209.

Survival and growth of slash pine seedlings lifted and planted in July and August compared favorably with those lifted and planted in December. If summer planting is successful, several advantages are obvious: a longer planting period and less chance of seedling losses when weather or other conditions prevent planting in the normal season and seasonal rush at nurseries will be somewhat relieved.

McLintock, T. F.

1964. Progress through research—and vice versa. Va. Forests 19(4): 8-11, 28.

Forestry progress reflects new research information, and research activity responds to action programs of progressive forest owners, State forestry organizations, and other research customers. Rapid development of extensive planting programs in the South sparked productive research at the Southeastern Forest Experiment Station in many fields—control of nursery diseases, improved planting techniques, tree improvement, etc. Balancing the applied phases, basic research at the Station is best illustrated in the field of fire research. Regional in scope and importance, problems are attacked by two teams of scientists specializing in physics, chemistry, meteorology, mathematics, and the forest sciences.

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1964. U. S. Forest Service research in North Carolina. Forest Farmer 23(8): 15-17, 33.

Research of USDA Forest Service is decentralized to permit close contact with needs of customers. In North Carolina—one of five states in Southeastern Forest Experiment Station territory—programs are centered at Asheville (also Station headquarters), Durham, and Franklin. Major activities include Forest Survey, management of mountain forests for better deer habitat, forest hydrology in the mountains and the Piedmont, silviculture of mountain hardwoods, fundamental research in forest entomology and pathology, and soil science with particular reference to the nutrient cycle of the forest.

———

1965. The hardwood situation in area III. The Unit 106: 36-38.

Hardwoods increasing in area but declining in quality present a complex and neglected problem in S.C., Ga., and Fla. Even-aged management promises best solution for regenerating most stands. Research on young stand management has high potential.

McLintock, T. F.

1966. Outlook for timber supply and demand. 45th Annu. Meetin Appalachian Sect. Soc. Amer. Forest. Proc. 1966: 2-8.

Based on consideration of some of the principal premises an conclusions presented in "Timber Trends in the United States this report attempts to answer the following three questions i terms of specific implications for the Southeast: (1) What is th future outlook for timber requirements?; (2) What is the preser status of our timber resource?; and (3) How well is our timbe supply likely to meet expected demands over the next severa decades?

McMinn, J. W.

1965. Precommercial thinning. Forest Farmer 24(12): 10-11.

A dense stand of 7-year-old slash pine was thinned to 200, 40 and 700 stems per acre, and the subsequent growth compared wit an unthinned check (3,500 stems per acre). The lightest thinnin showed greatest merchantable cubic-foot yield for a wide range o rotation ages, whereas the heaviest thinning resulted in greate sawtimber volume and the best potential net return from nava stores. This response shows value of determining managemen objectives early.

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1966. Phosphate aids tree growth. Fla. Cattleman & Livestock J. 30(8) 44-45.

One ton per acre more than pays for itself in forage production and tree growth is increased about 25 percent for at least 5 years

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1966. Site preparation aids longleaf regeneration. J. Forest. 64: 385-387

Site treatments were burning alone, burning followed by strip harrowing, burning followed by a single harrowing, and burning followed by a double harrowing. Stocking for the most intensive treatment was nine times that for burning alone.

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1967. Comparative fire resistance of two seed sources of South Florida slash pine. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res Note SE-68, 3 pp.

Twenty-seven percent of the saplings from a Hendry County, Florida, seed source, and only 16 percent of the saplings from a Polk County, Florida, seed source survived a spring wildfire. The fire occurred 8 years after outplanting on a study area in Charlotte County, Florida. Variation in bark thickness offers a partial explanation for the disparity in survival between sources.

McNab, W. H., and Ach, E. E.

1967. Prescribed burning improves Piedmont loblolly pine seedbeds. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-76, 2 pp.

An early fall prescribed burn of a seed tree stand in the Georgia Piedmont significantly aided in regeneration of loblolly pine (*Pinus taeda* L.). First year response was not observed because of inadequate seed supply. The seed crop the following year was sufficient to provide 59 and 46 percent milacre stocking on the burned and unburned seedbeds, respectively. The 1-year-old burned seedbed required 55 seeds for each established seedling, while twice as many seeds per seedling were needed on the unburned area.

Maddock, S. J., and Gehrken, G. A.

1967. Are company hunting policies understood by hunters? South. Lumberman 215(2680): 195, 198.

This article is a portion of a more comprehensive study to determine opportunities for outdoor recreation on privately owned lands. It is based on personal interviews with 170 (85 percent of a random sample of 200) male residents of Brunswick County, Virginia, to determine their awareness and understanding of policies established by four major pulp companies relating to use of their lands by hunters. The data obtained indicate a need for a more intensive effort to inform the hunting public of the privileges available as well as the restrictions established.

——— **Gehrken, G. A., and Guthrie, W. A.**

1965. Rural male residents' participation in outdoor recreation. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-49, 2 pp.

A random sample of 200 Brunswick County (Virginia) residents in 1965 to determine the contribution of commercial forest lands to the recreation activities of rural residents showed that hunting and fishing were much more popular than picnicking, hiking, swimming, boating and canoeing, camping, and nature walks.

Martin, R. E.

1967. Interim equilibrium moisture content values of bark. Forest Prod. J. 17(4): 30-31.

Presents preliminary data on equilibrium moisture content values of six species of pine and five species of hardwoods. Values were obtained at 25° C. over saturated salt solutions. Comparative EMC values for bark and wood are shown in curves, and tabular data are presented on EMC values of bark of the 11 species.

——— **and Cushwa, C. T.**

1967. Effects of heat and moisture on leguminous seed. Fifth Annu. Tall Timbers Fire Ecol. Conf. Proc. 1966: 159-175.

There is little in the literature about the effect of fire or artificial sources of heat on the germination of native legume seed.

Under field conditions, repeated fire favors repetitive abundant stands of native legumes which are important wildlife food plants.

Our findings indicate that dry heat, under laboratory conditions, did not increase germination of several species of native legume seed, but that moist heat, which more closely simulated conditions produced during prescribed burning, greatly increased germination rate and total germination of partridgepea (*Cassia nictitans*).

Marx, D. H.

1967. Ectotrophic mycorrhizae as biological deterrents to pathogenic root infections by *Phytophthora cinnamomi*. XIV. IUFRO-Congr. Proc. Vol. V (Sect. 24) Munich, 1967: 172-181.

Purported mechanisms for resistance of ectotrophic mycorrhizae to infection by *Phytophthora cinnamomi* were investigated. In agar culture, several mycorrhizal fungi inhibited up to 92 percent of 48 species of fungal root pathogens.

An antibiotic produced by *Leucopaxillus cerealis* var. *piceina* was identified as diatretyne nitrile. Minimal inhibition (20 percent) of zoospore germination of *P. cinnamomi* was detected at 50 p.p. billion, and 100 percent inhibition was detected at 2 p.p.m. Minimal inhibition (20 percent) to growth from mycelial discs of *P. cinnamomi* was detected at 0.5 p.p.m., and 100 percent inhibition was detected at 9 p.p.m. Bacteria were inhibited between 0.5 and 2.5 p.p.m. concentrations. *L. cerealis* var. *piceina* produced up to 12 p.p.m. of diatretyne nitrile in liquid culture. Diatretyne nitrile production was optimal during rapid growth and incipient autolysis phases. During continued autolysis the nitrile was reduced to diatretyne 3 and diatretyne amide which are antibacterial ant biotics. The symbiont produced the diatretynes in all asepti substrates which supported growth.

Fully developed mycorrhizae formed by the above fungu *Pisolithus tinctorius*, *Laccaria laccata*, *Suillus luteus*, and severa morphologically distinct forms of naturally occurring mycorrhiza on roots of loblolly and/or shortleaf pine were resistant to infectio when incubated with zoospores of *P. cinnamomi*. Short root initial covered with fungus mantles from adjacent mycorrhizae were no infected; whereas initials without mantle coverings were heavil infected. Diatretyne nitrile and diatretyne 3 produced by *L. cereali* in mycorrhizae of shortleaf reduced susceptibility of adjacent shor roots.

It was concluded that ectotrophic mycorrhizae are not onl beneficial to plant growth in a direct physiological manner bu also serve to reduce root infection by certain pathogens.

Marx, D. H., and Davey, C. B.

1967. Ectotrophic mycorrhizae as deterrents to pathogenic root infections Nature 213(5081): 1139.

A preliminary report concerning the resistance of matur ectotrophic mycorrhizae formed aseptically and also in greenhous pot culture on shortleaf (*Pinus echinata* Mill.) and loblolly (*P* *taeda* L.) pine seedlings to pathogenic infection by zoospores o *Phytophthora cinnamomi* Rands. It was concluded that mycorrhizae, in addition to their physiological importance, are beneficia to pine trees by functioning as biological deterrents to pathogeni attack. Trees with abundant mycorrhizal development, therefore should have less susceptible root tissue exposed to root pathogens than trees with few or no mycorrhizae.

——— **and Haasis, F. A.**

1965. Induction of aseptic sporangial formation in *Phytophthora cinnamomi* by metabolic diffusates of soil micro-organisms. Nature 206(4985): 673-674.

Aseptic sporangial formations on mycelia of *P. cinnamomi* were obtained by Millipore filter partition of this mycelia from nonsterile soil leachate containing bacteria. These bacteria produce an extracellular sporangial-inducing substance(s) (SIS) which is extremely unstable but essential to sporangial formation in *P. cinnamomi*. Any method employing the removal of living bacterial cells from close association with *P. cinnamomi* has failed.

——— **Haasis, F. A., and Nelson, R. R.**

1965. Failure of metabolic diffusates to induce oospore formation in *Phytophthora cinnamomi*. (Abstr.) J. Elisha Mitchell Sci. Soc. 81(2): 75-76.

Presents evidence that extracellular metabolites from single or paired (with oospores) cultures cannot induce oospore formation in self-sterile cultures of *P. cinnamomi* of either plus or minus compatibility. The results support the hypothesis that gametangial fusion is primary in the programing of oogenesis.

——— **and Zak, Bratislav**

1965. Effect of pH on mycorrhizal formation of slash pine in aseptic culture. Forest Sci. 11: 66-75.

Substrate pH strongly influenced mycorrhizal formation and growth of slash pine (*Pinus elliottii* var. *elliottii*) seedlings in aseptic culture. Vermiculite substrates changed the pH of unbuffered nutrient solutions from pH 3.0 to pH 6.4-6.7 in less than 48 hours after autoclaving. Sand substrates caused only slight changes. Small quantities of peat moss mixed with vermiculite adequately offset the buffering action of vermiculite and established stable pH reactions. All mycorrhizae developed best in less acid substrates.

Matthews, F. R.

1964. Some aspects of the biology and the control of southern cone rust. J. Forest. 62: 881-884.

Cone rust on southern pines was followed from development of basidiospores on evergreen oaks to infection of female strobili. Hydraulic spray applications of ferbam at 5-day intervals gave control in slash pine seed orchards.

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1967. 61. Southern cone rust. *Cronartium strobilinum* (Arth.) Hedgc. and Hahn, pp. 224-227. *In* A. G. Davidson and R. M. Prentice [ed.], Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. Dep. Forest. & Rural Develop., Canada, Pub. 1180.

Contribution on forest pest problems by the Working Group on Forest Insects and Diseases, North American Forestry Commission, FAO.

Merkel, E. P.

1964. Hydraulic spray applications of insecticides for the control of slash pine cone and seed insects. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-9, 7 pp.

Slash pines up to 40 feet in total height were protected from coneworm attack with BHC or Guthion. DDT did not give satisfactory protection from coneworms. Of the three tested, Guthion was the only insecticide which controlled the seedworm. A spray schedule is given for the control of coneworms and the seedworm.

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1967. Individual slash pines differ in susceptibility to seedworm infestation. J. Forest. 65: 32-33.

The degree of infestation by the seedworm, *Laspeyresia anaranjada* Miller, in mature slash pine cones, *Pinus elliottii* Engelm., was observed on 15 open-grown trees for 3 consecutive years. Certain trees sustained either consistently high or low levels of seedworm attack over the 3-year period, which suggested that genetic resistance may be present.

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1967. Insecticides for pine seed orchard insect control. USDA Forest Serv., S&PF, SA, Forest Nurserymen Conf. Proc. 1966: 152-157.

The present and future use of systemic insecticides for seed orchard insect control is emphasized and the advantages and disadvantages are discussed briefly. Past experiments with systemics for pine tip moth control are reviewed and the preliminary results of recent studies of the control of cone insects are presented.

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1967. Life history of the slash pine seedworm, *Laspeyresia anaranjada* Miller (Lepidoptera: Olethreutidae). Fla. Entomol. 50: 141-149.

The slash pine seedworm occurs throughout the natural range of its preferred host, slash pine (*Pinus elliottii* Engelm.), in the southern United States. Most of its period of larval development is spent feeding within seeds in second-year cones, and mature larvae overwinter in the cone axis. The life cycle is completed in 1 year.

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1968. Field screening of insecticides for control of the pine seedworm, *Laspeyresia anaranjada* Miller. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Note SE-97, 2 pp.

Three insecticides, Gardona®, fenthion, and Azodrin®, effectively controlled the pine seedworm, *Laspeyresia anaranjada*, on second-year slash pine cones in a field screening test.

Merkel, E. P., Squillace, A. E., and Bengtson, G. W.

1966. Evidence of inherent resistance to *Dioryctria* infestation in slas pine. Eighth South. Conf. Forest Tree Impr. Proc. 1965: 96-99.

Infestation of mature slash pine cones by *Dioryctria abietell* and *Dioryctria amatella* was recorded on 10 mature slash pines i a seed production area at Olustee, Florida, over a 3-year period The study suggests genetic control over coneworm attack an attack by *D. amatella*.

——— **and Yandle, D. O.**

1965. Mist blower applications of insecticides for cone insect control o slash pine. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res Note SE-52, 4 pp.

A field experiment to compare the effectiveness of hydrauli sprays with mist blower applications of insecticides for cone insec control showed that cone infestation by *Dioryctria* spp. wa significantly lower on all sprayed trees than on unsprayed tree at midseason and at cone harvest. The mist blower application o a 1.0-percent Guthion water emulsion gave significant control of th seedworm, *Laspeyresia anaranjada.*

Meskimen, George

1968. Miniature soil auger for pot sampling. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-88, 2 pp.

A carpenter's ship auger makes an efficient tool for sampling the soil in pots. The auger minimizes the size of sampling holes and is unhampered by large soil particles.

Metz, L. J., and Farrier, M. H.

1965. Forest soil fauna and the forest floor, pp. 25-31. *In* Forest-soil relationships in North America. 2nd N. Amer. Forest Soils Conf., Oregon State Univ. (1963).

A brief review of some problems of sampling, extracting, and identifying fauna of forest soil, especially mites, and a short account of the effect of burning and use of insecticides on them.

——— **and Wells, C. G.**

1965. Weight and nutrient content of the aboveground parts of some loblolly pines. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-17, 20 pp.

The aboveground parts of 10 loblolly pines, growing in the Piedmont section of South Carolina, were weighed and analyzed for N, P, K, Ca, and Mg. Nutrient values were placed on a weight basis to show distribution of the nutrients in trees ranging from 8 to 46 feet in height.

——— **Wells, C. G., and Swindel, B. F.**

1966. Sampling soil and foliage in a pine plantation. Soil Sci. Soc. Amer. Proc. 30: 397-399.

Analyses were made for N, P, K, Ca, and Mg on foliage from 256 young loblolly pine trees growing in a plantation. Soil samples from beneath each tree were also analyzed for the same nutrients. Only a small portion of the variation in foliage content could be accounted for by variation in the nutrient level of the soil. Recommendations (number of plots and number of trees) are given for sampling both foliage and soil.

Miller, Thomas, and Roncadori, R. W.

1966. Abjection of secondary sporidia of *Cronartium fusiforme*. Phytopathology 56: 1326.

The secondary sporidia of *Cronartium fusiforme* were found to be forcibly discharged from the spore cases of the primary sporidia. Abjection occurred when primary sporidia germinated on water agar and on various plants.

Moore, G. E.

1966. A technique for rearing the pales weevil, *Hylobius pales* (Herbst.). Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-66, 2 pp.

Concerns rearing the pales weevil on loblolly pine bolts in 40 pound lard cans. The precautions that should be taken and the rearing potential are given.

——— **and Clark, E. W.**

1968. Suppressing microorganisms and maintaining turgidity in coniferous foliage used to rear insects in the laboratory. J. Econ. Entomol. 61:1030-1031.

An aseptic technique is described that retards the growth of microflora attacking excised conifer stems kept in water, thus facilitating the rearing of foliage-feeding and tip-infesting insects. Treated foliage remained fresh for an average of 5 weeks or until the foliage was consumed, whereas untreated foliage averaged only 10 days. The technique is most useful when time or insufficient host material creates a difficult, expensive rearing situation.

Moore, W. H.

1967. Deer browse resources of the Atomic Energy Commission's Savannah River Project Area. Southeast. Forest Exp. Sta., U. S. Forest Serv. Resource Bull. SE-6, 28 pp.

Deer browse production and use measurements of the 200,000-acre area were made in 15 different pine and hardwood stand conditions using 380 sample locations. Measurements involved frequency sampling for occurrence and utilization of woody understory plant and estimates of weight of annual growth. In general, the better sites contained more desirable species and higher weight of desirable browse. Weight of desirable browse ranged from a low of 6 pounds per acre in young pine plantations to over 130 pounds per acre in some bottomland hardwoods. Only slightly more than 1 percent of all desirable species showed signs of utilization. Present population is estimated to be 2,000 animals. Carrying capacity is estimated to be near 10,000 deer.

——— **and Downing, R. L.**

1966. Some multiple-use benefits of even-aged management in the southern Appalachians. Soc. Amer. Forest. Proc. 1965: 227-229.

Even-aged management promises to benefit both forestry and recreation by providing such an abundance of regeneration following clearcutting that the deer herd is well fed, yet enough seedlings and sprouts escape to insure a well-stocked productive forest.

——— **and Johnson, F. M.**

1967. Nature of deer browsing on hardwood seedlings and sprouts. J. Wildlife Manage. 31: 351-353.

This study was conducted in Southern Appalachian cove hardwoods from 1960-1963. Three years after a heavy commercial cut, seedlings were almost four times as numerous as sprouts, yet received only one-fourth the use by white-tailed deer (*Odocoileus virginianus*): 3,520 seedlings received 14 percent use and 995 sprouts received 57 percent use. Preference seems more closely related to growth rate or succulence than to plant species. It was apparent that much more forage was produced than utilized.

Moore, W. H., Johnson, F. M., Oberheu, John, and Strode, D. D.

1964. Forage for deer. Wildlife in N. C. 28(7): 14-15.

Relative preference by deer of two clovers, red and ladino, an six grasses, orchard grass, Oklahoma brome, shade fescue, Kentuck 13 fescue, tall oatgrass, and Kentucky bluegrass, was determine by clipping small protected and unprotected sample plots period cally on the Pisgah National Forest.

Clovers, when available, were utilized much more heavily tha grasses. Heaviest clover consumption occurred during the sprin and summer and was almost completely consumed by late summe At this time, use of grasses began and increased throughout th fall and winter. Peak clover utilization occurred during earl summer and averaged approximately 350 pounds/acre/month (dr weight). Peak grass consumption occurred during late winter an averaged approximately 100 pounds/acre/month (dry weight)

——— **and Strode, D. D.**

1966. Deer browse resources of the Uwharrie National Forest. Southeas Forest Exp. Sta., U. S. Forest Serv. Resource Bull. SE-4, 20 p

Deer browse production and use measurements were included i a survey of timber resources on the Uwharrie National Forest Habitat measurements involved frequency sampling for occurrenc and utilization of woody understory plants and estimates of weigh of annual growth in 11 major forest types both in and out of th wildlife management areas. Data are presented showing produc tion and utilization of browse for each major strata recognize in the study. Data indicated that browse use exceeded the 40 per cent optimum level and that range deterioration was apparent.

Moyer, E. L., Jr.

1967. Controlling off-site hardwoods with 2,4-D amine concentrate. South east. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-77, 2 pp

Concentrated amine of 2,4-D was injected at 1-, 3-, and 5-inc intervals in southern red oak (*Quercus falcata* Michx.), hickor (*Carya* spp.), and flowering dogwood (*Cornus florida* L.) durin winter and summer seasons. Red oak was readily killed wit injections of 2,4-D spaced at 5-inch intervals and applied at eithe season. For dogwood and hickory, summer injection at 3-inc spacing gave a high percentage of kill.

Nelson, R. M.

1964. The National Fire Danger Rating System: derivation of sprea index for Eastern and Southern States. Southeast. Forest Exp Sta., U. S. Forest Serv. Res. Pap. SE-13, 44 pp.

Standards for locating, operating, and maintaining forest fir danger stations in Eastern and Southern States, including table and forms for deriving the Spread Index of the new National Fir Danger Rating System.

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1965. Windspeed and the probability of fire occurrence. USDA Forest Serv. Fire Contr. Notes 26(1): 15.

An analysis of more than 5,000 fires that burned in six protection units in the North and Southeast on days that had highly flammable fuels indicated that windspeed apparently had little effect on the probability of fire occurrence.

——— **and Schoch, M. S.**

1964. 1963 forest fires and fire danger in Connecticut, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, and West Virginia. USDA Forest Serv. Southeast. Forest Exp. Sta.

Thirteen separate reports containing tables and graphs analyzing forest fires and fire danger.

Nelson, R. M., and Schoch, M. S.
1965. 1964 forest fires and fire danger in Rhode Island. USDA Forest Serv. Southeast. Forest Exp. Sta.

Report contains tables and graphs analyzing forest fires and fire danger.

Nelson, R. R., and Hodges, C. S.
1965. A new species of *Curvularia* with a protuberant conidial hilum. Mycologia 57: 822-825.

A new species of *Curvularia* is described which is morphologically similar to *C. geniculata* but which differs in possessing a prominent protuberant conidial hilum. The importance of the conidial hilum in the taxonomy of *Curvularia* is discussed.

Nelson, T. C.
1964. Diameter distribution and growth of loblolly pine. Forest Sci. 10: 105-114.

The relationships between cubic-foot growth and diameter distribution, and residuals from cubic-foot growth equations and diameter distribution were tested on 103 plots of even-aged, managed loblolly pine. A series of diameter distribution characterizations using mathematical expressions of the entire distribution curve, mathematical expressions of individual attributes of the diameter distribution curve, and biological characterizations of it were computed. All of the 15 expressions of diameter distribution tested were rejected as useful expressions for characterizing merchantable cubic-foot growth. The probability of markedly reducing unexplained variation in merchantable cubic-foot growth in managed, even-aged loblolly pine with characterizations of diameter distribution is small.

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1965. Silvical characteristics of the commercial hickories. USDA Forest Serv. Southeast. Forest Exp. Sta. Hickory Task Force Rep. 10, 16 pp.

Presents the silvical characteristics of four true hickories and four pecan hickories, including climate, soils, and physiography, reproduction methods, and seedling development for each of the two groups, plus the major enemies and hazards of hickories.

——— **and Bennett, F. A.**
1965. A critical look at the normality concept. J. Forest. 63: 107-109.

This paper documents definitions on normality and full stocking—the subjective nature of the terminology concerning normality—and evaluation of the concept. The theoretical and practical limitations in the use of normality in growth and yield studies are developed, including relativity of normal tables, biological weakness of overstocking, correction of yields for normal stands, disregard for tree size, and lack of economic and management optimization.

Neunzig, H. H., and Merkel, E. P.
1967. A taxonomic study of the pupae of the genus *Dioryctria* in the Southeastern United States (Lepidoptera: Phycitidae). Ann. Entomol. Soc. Amer. 60: 801-808.

Detailed descriptions, figures, and a key are given for the pupae of *Dioryctria zimmermani* (Grote), *D. amatella* (Hulst), *D. disclusa* Heinrich, *D. clarioralis* (Walker), *D. pygmaeella* Ragonot, and *D. abietella* (Denis and Schiffermuller). In comparing findings of the present study with information in the literature, a difference was found in the number of setae present on pupae of so-called *abietella* of Florida and pupae of *abietella* (*abietivorella*) of northern United States and Canada. This apparently isolated population in the South possibly is not the same species as the more northern insect.

Neunzig, H. H., Rabb, R. L., Ebel, B. H., and Merkel, E. P.
1964. Larvae of the genus *Dioryctria* (Lepidoptera: Phycitidae) in the southeastern United States. Ann. Entomol. Soc. Amer. 57: 693-700.

Detailed descriptions, supplemented by illustrations and key, are presented for the last-instar larvae of *Dioryctria abietella, pygmaeella, disclusa, clarioralis, amatella,* and *zimmermani.*

Olson, D. F, Jr.
1967. The production and dispersal of hardwood seed. 1966 Symp. Hardwoods of the Piedmont & Coastal Plain Proc., Ga. Forest Res. Counc., Macon, Ga., pp. 26-28.

The seed characteristics of southern hardwoods are widely varied. Some of the better southern hardwood species are light-seeded, including yellow-poplar, sweetgum, cottonwood, and sycamore. All of these species produce frequent heavy crops. The tupelos bear a stone seed similar to cherry and birds play a large part in their dispersal. The heavy-seeded oaks are erratic seed producers, with bumper crops occurring every 5 to 7 years. Predators consume a large percentage of every acorn crop. In general, seed production of hardwoods is not a crippling limitation to regeneration.

——— **and Hooper, R. M.**
1968. Early survival and growth of planted northern red oak in the Southern Appalachians. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-89, 3 pp.

This paper presents 2-year survival and growth data for six northern red oak plantings, each containing three morphological seedling grades, over a range of site indexes from 76 to 98 feet at age 50.

Seedling survival averaged 94 percent, with no important differences due to seedling grade or site index. Height growth has averaged only 3 inches a year.

Ostrander, M. D., Campbell, R. A., and Bulgrin, E. H.
1964. A guide to log diagraming for eastern softwoods. USDA Forest Serv. Northeast. Forest Exp. Sta., 33 pp.

A handbook developed primarily as a teaching aid and field reference in diagraming eastern softwood logs, bolts, or felled and bucked trees. Contains definitions and describes procedures.

Page, R. H., and Applefield, Milton
1965. How effective is moisture control in your plant? Nat. Hardwood Mag. 39(6): 38-39, 42-43, 48-49, 54-55, 80.

Equilibrium moisture contents in a furniture plant ranged from 4.8 to 11.3 percent during a 2-week period in February. Heat and humidification during the test period were not effective in maintaining a constant equilibrium moisture content, a prerequisite to trouble-free furniture assembly.

Papa, K. E., Campbell, W. A., and Hendrix, F. F., Jr.
1966. Mating response in heterothallic isolates of *Pythium.* (Abstr.) Genetics 54(1), Part 2: 352-353.

Most isolates of *Pythium sylvaticum* fell into two distinct compatibility groups. Oospores were formed when the antheridial-producing strain mingled with the oogonial-producing strain. Mating type appears to be controlled by a complex genetic system.

——— **Campbell, W. A., and Hendrix, F. F., Jr.**
1967. Sexuality in *Pythium sylvaticum*: heterothallism. Mycologia 59: 589-595.

Morphological heterothallism was demonstrated in *Pythium sylvaticum* with the antheridia and oogonia restricted to different thalli. The presence of sexually reactive metabolic diffusates could not be demonstrated.

Patric, J. H., Douglass, J. E., and Hewlett, J. D.

1965. Soil water absorption by mountain and piedmont forests. Soil Sci. Soc. Amer. Proc. 29: 303-308.

Early absorption from uniformly moist mountain soils was related mainly to root concentration, but tended toward uniform absorption to 20 feet as soil dried. Nonhomogeneous soil horizons (piedmont) led to irregular early absorption, but still tended toward uniform extraction later on. The data indicate that where soil matric potential is kept low by frequent rain, most transpired water comes from densely rooted surface soil, whereas soil water well beyond rooting depths returns to the surface during long rainless periods.

Paul, J. T., Taylor, D. F., and Waters, M. P. III

1968. Some meteorological conditions associated with lightning-caused forest fires in southeastern Georgia. (Abstr.) Amer. Meteorol. Soc. Bull. 49: 56.

The total number of lightning-caused fires in Georgia (1959-1961) was 1,932, or 3.9 percent of all fires. Though not a serious statewide problem, Georgia Fire District 8 in southeast Georgia accounted for 64 percent of these with an occurrence rate four times the state average. Lightning accounted for 19 percent of all fires in District 8, these being common on only a few days during the summer. As many as 40 lightning fires have occurred in a single day, thus posing a severe local control problem.

Fire records from the Georgia Forestry Commission and hourly surface data from surrounding Weather Bureau and military weather stations were acquired for this study.

Perry, J. H., and Riebold, R. J.

1965. Strip clearcutting to regenerate longleaf pine. South. Lumberman 211(2632): 153-155.

A 45-year-old stand of longleaf pine was successfully regenerated by clearing and disking strips 200 to 300 feet wide and leaving intervening seed source strips 1 chain in width. Milacre stocking averaged 60 percent, with good distribution over the cleared strips. When cattle and hogs had access to the area, the damage was disastrous.

Peter, R. K.

1965. Skiing on sawdust. Forest Prod. J. 15(1): 30.

Sawdust is more permanent than artificial snow and far less costly. Dry sawdust is much faster than wet sawdust. Studies are underway to determine the effect of wood particle size and chemical additives on skiing speed.

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1966. Skiing on sawdust. Parks & Recreation 1(3): 245, 248.

Over 50 additives or materials were tested or inspected for use with the sawdust. Both wet and dry sawdust slopes are skiable.

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1967. Influence of sawing methods on lumber grade yield from yellow-poplar. Forest Prod. J. 17(11): 19-24.

Describes an analytical method by which 50 yellow-poplar logs were theoretically sawn more than 2,800 times, with each sawing involving different sawline combinations and defect orientation. Data obtained indicate sawing method can make a difference of up to $39 per MBF. Sawing a log on three faces only produced higher lumber value than sawing on four faces. Turning for grade produced better than average value, while gang-sawing plus ripping for grade, produced lumber values only slightly higher than did turning for grade.

Pharis, R. P., Barnes, R. L., and Naylor, A. W.

1964. Effects of nitrogen level, calcium level, and nitrogen source upon the growth and composition of *Pinus taeda* L. Physiol. Plant. 17(3) 560-572.

Seedlings of loblolly pine were grown in sand culture at two concentrations of nitrogen (10 and 75 p.p.m. N) and calcium (0 and 200 p.p.m. Ca) for 4 months to determine which form of nitrogen was used most readily and to learn if there was an effect of calcium on nitrogen metabolism. Three sources of nitrogen were used: nitrate, ammonium, and urea. A number of indicators of growth were followed, and chemical analyses were made of foliage and roots. In general, the urea source resulted in greatest growth and nitrogen content of the seedlings. Nitrogen source had a pronounced effect on free amino acids in seedlings, with ammonium seedlings containing the most and nitrate seedlings the least. Nitrogen deficiency symptoms developed in all 10 p.p.m. N treatments. Calcium deficiency symptoms were not apparent at 0 p.p.m. Ca. Presence of Ca influenced N content of seedlings and N source affected Ca content of seedlings.

Pharo, J. A., and Lamb, R. C.

1966. Standardized rain gage tests. (Abstr.) Amer. Meteorol. Soc. Bull. 47: 469.

Proposes procedures that will facilitate precipitation measurement comparisons.

Pierce, D. A., McCambridge, W. F., and Moore, G. E.

1968. Control of pinyon needle scale with dimethoate. J. Econ. Entomol. 61: 1697-1698.

This paper reports on the last in a series of tests to find a control for *Matsucoccus acalyptus* Herbert. Water-emulsion formulations of 0.5 to 1.0 percent dimethoate gave similar and effective results. Addition of a surfactant did not significantly increase mortality. Proper timing is important; spray should be applied to all eggmass concentrations when eggs begin to hatch.

Platt, W. D., Cowling, E. B., and Hodges, C. S., Jr.

1965. Resistance of coniferous root wood and stem wood to decay by *Fomes annosus.* (Abstr.) Phytopathology 55: 130-131.

Decay resistance of sapwood from roots and stems of eight coniferous species was determined in a complete factorial experiment using 16 tissue isolates of *Fomes annosus* from the same eight species. Among the wood species tested, *Juniperus virginiana* was most resistant; *Pinus resinosa, P. virginiana,* and *P. palustris* were intermediate; and *P. echinata, P. elliottii* var. *elliottii, P. strobus,* and *P. taeda* were least resistant. Stem wood of all species was more resistant than root wood.

Powell, W. M., Hendrix, F. F., Jr., and Marx, D. H.

1968. Chemical control of feeder root necrosis of pecans caused by *Pythium* species and nematodes. U. S. Dep. Agr. Plant Dis. Rep. 52: 577-578.

Following various nematocidal and fungicidal soil treatments of pecan in decline in south Georgia, it was found that treatments had no effects on soil pathogens associated with decline syndrome. The soil treatments, however, significantly increased mycorrhizal development by *Scleroderma bovista* and eliminated decline symptoms. The field correlation of an increase in mycorrhizal development with a decrease in root disease development is the first report of the biological control of root diseases by ectotrophic mycorrhizae.

Powell, W. M., Owen, J. H., and Campbell, W. A.

1965. Association of phycomycetous fungi with peach tree decline in Georgia. U. S. Dep. Agr. Plant Dis. Rep. 49: 279.

Since 1962, associated with several years of above average rainfall, peach trees of all ages have died in large numbers throughout central Georgia. All indications are that losses will be particularly severe in 1965. *Phytophthora cinnamomi, P. cactorum, P. parasitica, Pythium vexans, P. ultimum, P. irregulare*, and a number of other *Pythium* species have been isolated from orchard soils suggesting that these recognized pathogens have been involved in the fine root necrosis associated with the decline and mortality.

Powers, H. R., Jr.

1964. Factors to be considered in making disease surveys. USDA Forest Serv., Third Annu. Forest Insect & Dis. Contr. Work Conf. Proc., Atlanta, 1964: 138-140.

Factors such as a well thought-out set of objectives, financial support, technical skill of available manpower, material, and time available are related to the planning and conducting of forest tree disease surveys.

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1964. Forest diseases—the problem and how to meet it. Forest Farmer 23(7): 36-37.

A generalized review of economically important tree diseases in the South and measures for combating them.

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1966. Tree diseases—the problem and how to meet it. Forest Farmer Manual 25(7): 85-86.

A review of forest tree disease problems in the South and the measures for combating them. Current research on these diseases is also reviewed.

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1968. Current appraisal of forest tree diseases in the South. Forest Farmer Manual 27(7): 44-45.

A review of forest tree disease problems in the South and the measures for combating them. Current research on these diseases is also discussed.

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1968. Distance of needle infection from stem affects likelihood of gall development on slash pine by *Cronartium fusiforme*. Phytopathology 58: 1147-1149.

Slash pine seedlings were inoculated with sporidia of *Cronartium fusiforme* by hypodermic injection. Injection points were in the stem and 2, 5, 10, and 20 mm. out from the stem on the cotyledons. Microscopic examination revealed that the fungus was well established in the majority of the plants sampled, regardless of the point of injection. Subsequent stem gall development was directly related to the distance of the inoculation point from the stem, because mycelium from more distant infections did not reach the stem during the normal life span of the cotyledons.

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1968. Minimizing losses in pine plantations due to diseases. 7th Auburn Forest. Forum Proc. 1968: 9-14.

Fusiform rust, comandra rust, and annosus root rot are among the most important diseases of southern pines in plantations within the State of Alabama. The losses caused by these diseases and the control measures now being used to reduce these losses are discussed. The current status of research on each of these disease problems is also reviewed.

Powers, H. R., Jr., Hepting, G. H., and Stegall, W. A., Jr.

1967. Comandra rust on loblolly pine in eastern Tennessee. U. S. Dep Agr. Plant Dis. Rep. 51: 4-8.

Comandra rust has been known in eastern Tennessee on lobloll and ponderosa pine since 1951, and probably resulted from th introduction of diseased planting stock. Recent widespread plantin of loblolly pine in this area has resulted in heavy losses from thi disease. Until more information becomes available, Virginia pin is being recommended as a substitute species for planting in area where the alternate host, *Comandra umbellata,* occurs.

——— **and Roncadori, R. W.**

1966. Teliospore germination and sporidial production by *Cronartiu fusiforme.* U. S. Dep. Agr. Plant Dis. Rep. 50: 432-434.

Field collections of telial columns of *Cronartium fusiforme* fro infected oaks were made at weekly intervals and subjected to conditions favorable for teliospore germination. Maximum germinative capacity occurred within a 3-week interval from late Apri through mid-May 1965. Production of basidiospores droppe shortly after the third week in May, and by early June had essentially stopped.

——— **and Stegall, W. A., Jr.**

1965. An evaluation of cycloheximide (Acti-dione) for control of white pine blister rust in the southeast. U. S. Dep. Agr. Plant Dis. Rep. 49: 342-346.

Acti-dione was tested in a range of different concentrations from 100 to 300 p.p.m. for control of blister rust on eastern white pine. Eastern and western fuel oils were also compared for effectiveness as solvents and carriers of the antibiotic. Data taken over a 5-year period following infection showed that no control was obtained with the antibiotic at any of the concentrations used, or with either of the fuel oil solvents.

Ripley, T. H.

1966. Rehabilitation of forest recreation sites. Soc. Amer. Forest. Proc. 1965: 35-36.

Discusses important factors in the rehabilitation of developed recreation sites.

——— **and Halls, L. K.**

1966. Measuring the forest wildlife resource *In* Measuring the southern forest. La. State Univ. Sch. Forest., Fifteenth Annu. Forest Symp. Proc. 1966: 163-184.

A philosophical discussion and technical guide for those commercial forest managers who recognize the aesthetic, sociopolitical, and economic desirability of wildlife and wish to capitalize on this important resource. It discusses the relative merits of animal population census techniques and outlines methods which may be used to measure the productivity of the habitat.

——— **and Perkins, C. J.**

1965. Estimating ground supplies of seed available to bobwhites. J. Wildlife Manage. 29: 117-121.

Undisturbed soil and litter samples from pinelands in Georgia were used successfully to estimate the amount of cast seed with good precision, limited sampling effort, and low cost.

——— **Wilhite, L. P., Downing, R. L., and Harlow, R. F.**

1965. Game food plants in slash-longleaf flatwoods. Sixteenth Annu. Conf. Southeast. Assoc. Game & Fish Commrs. Proc. 1962: 35-44.

Wiregrass and palmetto understory types of the pine flatwoods were superior for quail and turkey when compared to the gallberry types.

Roberts, D. R.

1968. Effect of wounding on the composition of slash pine oleoresin: a preliminary report. (Abstr.) ASB Bull. [Assoc. Southeast. Biol.] 15(2): 53.

Gas chromatographic analysis of slash pine (*Pinus elliottii* Engelm. var. *elliottii*) oleoresin revealed that wounding of the trees, as in a naval stores operation, greatly changed the terpene hydrocarbon composition of the oleoresin from above, but not below, the wounded area (face). Generally the percentage of alpha-pinene in the turpentine portion of the oleoresin decreased, whereas beta-pinene and beta-phellandrene percentages increased. The effect of wounding on oleoresin composition was evident as much as 10 feet above the wounded area.

Experiments with small wounds (micro-chips), designed to determine the rate of composition change, failed to detect large differences; but minor effects of wounding were evident after 1 week. Experiments using fullface wounds (streaks) will be continued to investigate more fully the rate of composition change.

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1968. Use of the solid sample technique for pine oleoresin gas chromatographic analysis. J. Gas Chromatogr. 6: 126-127.

Injection of solid samples of pine needle, wood, and bark tissues allows gas chromatographic analysis of their monoterpene hydrocarbons without exudation or extraction of the oleoresin. This technique should also be useful for gas chromatography of volatile compounds from many other types of plant tissue.

Robinson, V. L.

1965. A changing hardwood market: the furniture industry. Forest Prod. J. 15(7): 277-281.

Traditional wood furniture faces heavy competition from metal and plastics. The impact of style, design, and substitution upon lumber consumption in household and nonhousehold furniture production is analyzed. Author concludes that, if hardwoods are to hold their future markets, ways and means must be found to reduce high labor requirements in wood furniture manufacturing.

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1966. The southern pine stud market for Georgia house construction. South. Lumberman 213(2656): 121-123.

Georgia builders preferred western studs because the southern pine studs marketed lacked dimensional stability. They complained that southern pine was too wet or green and warped too much.

——— **and Eickhoff, W. D.**

1966. Structural materials used in Georgia homes. Ga. Agr. Exp. Sta. Bull. N.S. 183, 18 pp.

Information from 87 builders was tabulated for the amounts and types of structural materials used to frame and cover the floor, the exterior and interior walls, the ceiling, and the roof areas of single-family houses built in Georgia during 1965.

Rodenbach, R. C.

1966. Southern yellow pine log overruns. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-56, 2 pp.

A table of overrun by log d.i.b. classes for Doyle, Scribner, and International ¼-inch log rules is presented.

Romancier, R. M.

1965. 2,4-D, 2,4,5-T, and related chemicals for woody plant control in th southeastern United States. Ga. Forest Res. Counc. Rep. 16, 46 pp

This paper is a comprehensive review of the literature on th uses of 2,4-D, 2,4,5-T, and other related chemicals for the contro of a wide variety of woody plants.

———— 1966. How to use chemicals to kill brush & trees. Crops & Soils 18(9) 10-13.

This article was prepared to inform farmers and land manager of the most effective chemicals and application methods for th control of tree and brush species. 2,4-D, 2,4,5-T, picloram, an fenuron are discussed, and a number of methods for applying thes chemicals at recommended concentrations are given.

———— 1966. Silvicides as an aid in hardwood management. Forest Farme 25(9): 6-7.

Chemicals and application methods available to the hardwoo land manager or forester.

———— **and Harms, W. R.**

1965. The relative phytotoxicity of several oils to tree foliage. South Weed Conf. Proc. 18: 322-328.

The phytotoxicity of 12 oils to the foliage of loblolly pine, turke oak, sweetgum, and red maple was evaluated, and certain oil prop erties correlated with leaf tissue damage. Aromatic content an flash point were associated with damage to all four species; sulfu content was related to damage in three species. The effect of sun light appeared significant only on sweetgum. None of the oils teste proved completely harmless to tree foliage.

Roncadori, R. W.

1965. The pathogenicity of secondary basidiospores of *Cronartium fusiforme.* (Abstr.) Phytopathology 55: 1074.

Secondary basidiospores, formed when primary basidiospores fall on nonhost tissue, were found pathogenic on pines. The secondary basidiospores may serve in nature to increase longevity and distance of dissemination of *Cronartium fusiforme.*

———— **and Matthews, F. R.**

1966. Storage and germination of aeciospores of *Cronartium fusiforme.* Phytopathology 56: 1328-1329.

Vacuum-dried aeciospores stored under vacuum at 5° C. lost little viability after 77 weeks. Rehydration of stored aeciospores for 24 hr. greatly increased the percentage germination over nonrehydrated spores. Cardinal temperatures for germination of stored aeciospores were 5° and 30° C., with an optimum of 20° C. No difference in infectivity between vacuum-dried-stored and fresh spores was noted.

Ross, E. W.

1966. Incidence of *Polyporus tomentosus* in slash pine plantations in the southeastern United States. U. S. Dep. Agr. Plant Dis. Rep. 50: 527.

Polyporus tomentosus, the cause of red root and butt rot, was reported in slash pine plantations at the Manchester State Forest, South Carolina; Hampton, South Carolina; Yulee, Florida; and Bainbridge, Georgia. Sporophores of the fungus were always found in the face of basal stem cankers caused by *Cronartium fusiforme.* A survey of the Bainbridge, Georgia, plantation showed 1.6 percent of the total trees (2,228) examined had *P. tomentosus* sporophores, and 8 percent with basal cankers (446) had sporophores.

Ross, E. W.

1967. Association of *Cylindrocladium scoparium* with mortality in a 27-year-old yellow-poplar plantation. U. S. Dep. Agr. Plant Dis. Rep. 51: 38-39.

Cylindrocladium scoparium Morgan was isolated from brownish-black necrotic areas in the cortical region of roots from dead and dying yellow-poplar (*Liriodendron tulipifera* L.) trees in a 27-year-old plantation. This report is the first known to associate this fungus with extensive root damage and mortality in trees beyond the seedling stage.

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1967. Practical control of *Fomes annosus* in southern pines. XIV. IUFRO-Congr. Proc. Vol. V (Sect. 24) Munich, 1967: 321-324.

Data from this study show no natural infection by *Fomes annosus* in south Georgia from April through August and only low rates of natural infection in North Carolina from May through September. The same general trend in colonization was found in stumps artificially inoculated with *F. annosus* in both study areas, except that higher percentages of stumps were colonized. Temperature data showed that both stump and air temperatures attained levels above the mycelial thermal inactivation time (40° C. for 2 hr.) of *F. annosus* for several consecutive days from April through September in Georgia and from mid-June to the first of September in North Carolina. Thinning operations may be conducted during late spring and summer months in the southeastern United States with minimum danger of stump infection by *F. annosus.*

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1968. Duration of stump susceptibility of loblolly pine to infection by *Fomes annosus.* Forest Sci. 14: 206-211.

During February, in Georgia, loblolly pine (*Pinus taeda* L.) stump surfaces are highly susceptible to infection by *Fomes annosus* up to 12 days after the tree is felled. A rapid increase in the incidence of *Peniophora gigantea* after 12 days apparently limited further colonization of the stumps by *F. annosus. Trichoderma viride* and other fungi had no apparent effect on colonization of the stump surfaces by *F. annosus.* Bacteria did not appear to limit colonization by *F. annosus* one day after the stump surface was exposed. Based upon results of this experiment, chemical stump protectants to control *F. annosus* on loblolly pine must provide protective action for at least 12 days. Seasonal thinning operations to control *F. annosus* should not be carried out closer than 2 weeks to known periods of high *F. annosus* infection.

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1968. Sand pine, a new host of *Fomes annosus.* U. S. Dep. Agr. Plant Dis. Rep. 52: 635.

Fomes annosus (Fr.) Cke. was isolated from 8-year-old planted sand pine (*Pinus clausa* (Chapm.) Vasey) near Rincon, Georgia. This is the first known report of sand pine as a host of *Fomes annosus.*

——— **and Driver, C. H.**

1966. Relation of temperature and time of cutting to colonization of slash pine stumps by *Fomes annosus.* (Abstr.) Phytopathology 56: 897-898.

It was determined from plots established in a thinned slash pine stand in south Georgia over a 12-month period that colonization of stumps by *Fomes annosus* was lowest during the late spring and summer months (June-August). Stump and air temperatures recorded during this period exceeded the thermal inactivation time (40° C. for 2 hours) of actively growing *F. annosus* mycelium. Thinning during the summer may appreciably reduce infection.

Ross, E. W., and Hodges, C. S., Jr.

1964. *Fomes annosus* infections in young slash pine plantations. (Abstr. Phytopathology 54: 904.

Fomes annosus was found infecting young slash pine seedling on clearcut areas in north Florida. Several localized areas ha over 20 percent infection, and in every case where excavations wer made there was a root contact between the infected seedling an a dead stump.

Roth, L. F., and Kuhlman, E. G.

1966. *Phytophthora cinnamomi*, an unlikely threat to Douglas-fir forestry Forest Sci. 12: 147-159.

The data show that *Phytophthora cinnamomi* is unlikely t become a problem in forests of the Pacific Northwest.

Ruehle, J. L.

1964. Nematodes and trees. Arborist's News 29(4): 25-30.

A review of the problem caused by plant-parasitic nematode attacking trees, and the damage in nurseries, plantations, and i mature forest stands.

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1964. Plant-parasitic nematodes associated with pine species in souther forests. U. S. Dep. Agr. Plant Dis. Rep. 48: 60-61.

A listing of the parasitic nematode genera associated wit southern pine species in both planted and natural stands.

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1965. Nematodes, the overlooked enemies of tree roots. 40th Int. Shad Tree Conf. Proc. 1964: 60-67.

A general discussion of nematodes, their nature, life cycles, th damage they do to tree roots and methods of combating them i ornamental plantings.

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1966. Nematodes parasitic on forest trees. I. Reproduction of ectoparasites on pines. Nematologica 12: 443-447.

Seedlings of nine species of pines native to the Southeast were grown in 20-cm. pots in the greenhouse and inoculated with five different species of ectoparasitic nematodes. Population increase after 9 months indicated a positive host-parasite relationship for a given nematode-pine combination. Ring (*Criconemoides xenoplax*), sheath (*Hemicycliophora vidua*), spiral (*Helicotylenchus dihystera*), stunt (*Tylenchorhynchus claytoni*), and stubby-root (*Trichodorus christiei*) nematodes parasitized and reproduced on at least five of the species tested. Loblolly (*Pinus taeda*), sand (*P. clausa*), slash (*P. elliottii* var. *elliottii*), and shortleaf (*P. echinata*) pine were hosts for all five nematodes tested.

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1967. Distribution of plant-parasitic nematodes associated with forest trees of the world. USDA Forest Serv. Southeast. Forest Exp. Sta., 156 pp.

This compilation of the worldwide distribution of forest nematodes is divided into two sections. Section 1 shows the distribution of nematodes commonly recognized as plant parasites along with the tree species with which they are associated. The geographical location is shown by country and, when possible, by state in the United States. Under each host species named in Section 2, nematodes of known or suspected importance are listed in alphabetical order. A listing of 237 literature citations is given.

(Limited distribution.)

Ruehle, J. L.

1967. Sting nematode damage to sycamore seedlings. (Abstr.) Nematologica 13: 151.

Sycamore seedlings in a greenhouse test exposed to sting nematodes exhibited necrosis of fibrous roots, galling of root tips, and reduced fresh weight of tops and roots. This test showed that sting nematode is highly damaging to sycamore seedlings.

———— 1968. Nematodes in forest soils, pp. 38-41. *In* Forest fertilization theory and practice symposium 1967. Tenn. Val. Authority, Muscle Shoals, Ala.

Nematode classification, modes of attack, effect of tree nutrition and growth, and control are discussed. The conclusion stresses the importance of nematodes in studies of forest fertilization.

———— 1968. Pathogenicity of sting nematode on sycamore. U. S. Dep. Agr. Plant Dis. Rep. 52: 523-525.

Under greenhouse conditions sting nematode (*Belonolaimus longicaudatus* Rau) proved to be highly damaging to sycamore seedlings (*Platanus occidentalis* L.). After 9 months seedlings exposed to either low or high inoculum levels exhibited necrosis of fibrous roots, galling of root tips, and reduced fresh weight of tops and roots.

———— 1968. Plant-parasitic nematodes associated with southern hardwood and coniferous forest trees. U. S. Dep. Agr. Plant Dis. Rep. 52: 837-839.

A geographical tabulation is presented to show new plant-parasitic nematode associations with southern forest hardwoods and conifers other than pines. It was compiled from results of a general nematode survey started by the Forest Service in 1961.

———— **May, J. T., and Rowan, S. J.**

1966. Nursery fumigation trial with Vorlex. USDA Forest Serv. Tree Planters' Notes 76: 4-7.

If Vorlex is used in nurseries, it should be applied under a polyethylene cover. Though Vorlex gave no improvement over methyl bromide in this test, some nurserymen may prefer it because it is easier and safer to handle.

———— **and Sasser, J. N.**

1964. Additional data on results of nematocidal fumigation in pine plots in North Carolina. U. S. Dep. Agr. Plant Dis. Rep. 48: 534-536.

Fumigation of outplanting sites resulted in increased growth of planted slash pine seedlings. Methyl bromide was superior to D-D, but both treatments gave better subsequent growth than growth on non-fumigated sites.

Ryan, P. W.

1966. Forest fires and fire danger in Georgia: a six-year summary, 1959-1964. Ga. Forest Res. Counc. Res. Pap. 39, 31 pp.

The fire occurrence rate in Georgia rose slightly between 1959 and 1964, indicating that the overall level of risk in the state increased. The burned area rate decreased each of these 6 years, indicating that the overall efficiency of fire suppression activities in Georgia increased during that time.

Ryan, P. W.

1967. The National Fire Danger Rating System—its present status and operation. 27th Annu. South. States Forest Fire Contr. Conf. & South. States Inform. & Educ. Meeting 1966: 67-86.

A brief background of the system development, along with specific examples of operational errors being made by system users. Pertinent data from Alabama are used to illustrate how the spread index correlates with fire business in that state.

——— **and Pachence, A. M.**

1965. An analysis of 1964 forest fires and fire danger in Georgia. Ga. Forest Res. Counc. Res. Pap. 30, 44 pp.

A summary of the fire situation in Georgia for the year 1964. Various fire relationships are discussed and illustrated, including the relationship of spread index to fire occurrence and burned area, major fire causes, and fire occurrence by month and time of day.

——— **and Pachence, A. M.**

1967. An analysis of 1965 forest fires and fire danger in Georgia. Ga. Forest Res. Counc. Res. Pap. 44, 23 pp.

A summary of the relation of spread index (national meter system) to fire occurrence and acres burned in Georgia for 1965, together with a trend analysis comparing 1965 fire business with previous years. Numbers of fires by cause, month, and time of origin are included.

——— **and Pachence, A. M.**

1967. An analysis of 1966 forest fires and fire danger in Georgia. Ga. Forest Res. Counc. Res. Pap. 47, 21 pp.

The eighth report of a continuing study designed to document the short- and long-term relationships between fire danger and fire business in Georgia. The spread index is used as the basis for graphical and tabular comparisons of fire activity in the state.

——— **and Pachence, A. M.**

1968. An analysis of 1967 forest fires and fire danger in Georgia. Ga. Forest Res. Counc. Res. Pap. 56, 21 pp.

The ninth report of a continuing study designed to document the short- and long-term relationships between fire danger and fire business in Georgia. The spread index is used as the basis for graphical and tabular comparisons of fire activity in the state.

Sackett, S. S.

1968. A field trial for regulating prescribed fire intensities. USDA Forest Serv. Fire Contr. Notes 29(3): 5-6.

A prescribed fire demonstration in the Coastal Plains of South Carolina indicated that spot ignitions spaced close together created more crown scorch than those spaced wider apart. If further investigations conducted over a normal range of fuel and weather conditions confirm these interpretations, the prescribed burner will have another means of regulating fire intensities at his disposal.

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1968. Prescription burning in pine plantations. 7th Auburn Forest. Forum Proc. 1968: 19-29.

When used correctly, prescription burning in young pine plantations (10 to 20 feet tall) is an inexpensive and effective way to minimize fuel hazards and reduce the risk of wildfire damage. Fuel and weather conditions must be carefully considered when burning in young stands; initial firing operations are usually limited to backfires. In followup burning, head or possibly spot fires can be used.

In addition to hazard reduction, *Fomes annosus* and brown spot can be reduced by properly timed prescribed burning.

Sackett, S. S., and DeCoste, J. H.

1967. A new mobile fire laboratory. USDA Forest Serv. Fire Contr. Notes 28(4): 7-9.

A new mobile fire laboratory has been put into service by the Southern Forest Fire Laboratory in Georgia. The mobile unit is used to document fires, both high-intensity (blowup) wildfires and prescribed fires. The basic unit is a house trailer drawn by a 3/4-ton truck. The inside of the trailer has been developed into a compact laboratory containing a host of scientific and electronic equipment, much of which is specifically designed for fire research. Fire weather, fuel conditions, fire behavior, and fire temperatures may all be scientifically documented.

Sampson, G. R.

1967. Markets for wood in remodeling and repair. South. Lumberman 215(2680): 161-162.

Market opportunities are developing for wood products in the field of remodeling and adding to existing homes. To take advantage of these opportunities wood products manufacturers need to assume an active role in promoting remodeling. They should also consider taking the lead in developing wood products which can be used in a systems approach to urban rehabilitation projects.

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1967. Residential remodeling and repair: big market for wood. Forest Prod. J. 17(7): 13-15.

Expenditures for residential remodeling and repair are expected to increase from $11.7 billion in 1963 to $26.6 billion in 2000. Wood products manufacturers stand to lose a large portion of the residential remodeling and repair market if they fail to direct promotional and production efforts toward it.

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1968. Wood or non-wood — which is promoted more? South. Lumberman 217(2704): 198-199.

For selected periodicals directed toward homeowners and builders, the volume of advertising for wood building products was greater than for competing products for most specific uses. Advertising volume in periodicals directed toward architects was greater for non-wood products than for competing wood products in each use category.

——— **and Fasick, C. A.**

1967. Southern pine glulam industry: market status. Forest Prod. J. 17(11): 11-13.

The volume of southern pine lumber used for laminating more than doubled over the last 5 years. Church construction accounted for more than half the value of southern pine laminated products sold in 1965. Most laminators are optimistic about the potential for southern pine laminates in commercial and industrial building construction.

Saucier, J. R., and Hamilton, J. R.

1967. Within-tree variation of fiber dimensions of green ash. Ga. Forest Res. Counc. Res. Pap. 45, 6 pp.

Variability of the fiber length, cell wall thickness, and cell diameter was closely associated with horizontal position from the pith. Much less variation occurred with height or radial location within trees. The greatest changes in cell dimension occurred in a core of wood surrounding the pith which contained approximately five annual rings and extended the length of the tree.

Application of these data will be helpful to industry in selecting material for products which contain minimal cellular variation.

Saucier, J. R., and Taras, M. A.

1966. Specific gravity and fiber length variation within annual height increments of red maple (*Acer rubrum* L.). Forest Prod. J 16(2): 33-36.

Specific gravity and fiber length in 1-year-old red maple (*Acer rubrum* L.) sprouts were investigated from samples taken at the midpoint of each sample internode. Specific gravity does not vary appreciably between internodes of 1-year-old sprouts except at the last formed internodes near the apex, where it decreases rapidly. Fiber length, on the other hand, does vary significantly between internodes, becoming progressively shorter from the base to the apex of the sprouts.

———— **and Taras, M. A.**

1966. Wood density variation among six longleaf pine seed sources grown in Virginia. J. Forest. 64: 463-465.

Longleaf pine from six seed sources were grown in Virginia and examined for specific gravity differences after eight growing seasons. One seed source from Florida had significantly lower specific gravity than other sources tested. Additional data indicated that the Florida seed source was less frost resistant than other sources; this difference may have been associated with its low specific gravity. Although data indicated a racial difference in specific gravity, a valid conclusion cannot be made in view of a confounding with incompatible environment. When the Florida seed source was omitted from the analysis of variance, there was no significant difference in specific gravity of five seed sources.

———— **and Taras, M. A.**

1967. Wood density and percent summerwood variation among nine loblolly pine seed sources grown in Alabama. Ninth South. Conf. Forest Tree Impr. Proc. 1967: 115-119.

Loblolly pine from nine seed sources was planted in central Alabama and examined for specific gravity and percent summerwood in its thirteenth growing season.

One seed source from Maryland was significantly greater (0.435) than the Georgia seed source (0.393). Excluding these high and low values, there were only 0.02 unit in specific gravity separating the remaining seven seed sources. Percent summerwood was not significantly different among seed sources.

There were no clear-cut trends in geographic variation but specific gravity and percent summerwood tended to be associated with latitude, increasing from south to north, while volume and dry weight tended to be associated with longitude, decreasing from east to west.

Performance of coastal North Carolina seed sources was above average in all properties examined. The southwest Georgia seed source ranked first in volume and last in specific gravity; but in spite of its low specific gravity, it ranked second in wood dry weight.

The genetic component of geographic variation in specific gravity does not appear to be large.

Schroeder, J. G., Campbell, R. A., and Rodenbach, R. C.

1968. Southern pine log grades for yard and structural lumber. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Pap. SE-39, 9 pp.

This paper presents the Forest Service standard log grades for southern pine. They were developed from analysis of tree grade data and replace the previously used knot-count grades. The log grades are applicable to loblolly, shortleaf, pond, longleaf, and slash pine logs that will be sawed into standard yard and structural lumber.

Schroeder, J. G., Campbell, R. A., and Rodenbach, R. C.

1968. Southern pine tree grades for yard and structural lumber. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Pap. SE-40, 15 pp.

This paper presents the Forest Service standard tree grades for southern pine, developed on the basis of lumber recovery studies conducted throughout the South. The grades are applicable to loblolly, shortleaf, pond, longleaf, and slash pine trees that will be sawed into standard yard and structural lumber.

Schultz, A. J.

1965. Replacement planting, pp. 75-83. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Cases are cited in which interplanted slash pine failed when planted 1 and 3 years after the original planting. Reinforcement planting should be used only in large fail spots. Guidelines are given to help in deciding at what level of stocking complete replanting should be done.

Schultz, R. P.

1968. Soil or foliar fertilization of well-drained and flooded slash pine seedlings. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-32, 8 pp.

One-year-old slash pine seedlings were grown for 9 months under two soil-moisture and four N + P fertilization treatments. Flooding increased seedling mortality and decreased growth. Foliar fertilized seedlings did not grow better than unfertilized seedlings either under well-drained or flooded conditions. Under well-drained conditions, seedlings receiving soil fertilization or foliar plus soil fertilization had more than double the dry-weight increment and one-quarter more height growth than unfertilized seedlings. Under flooded conditions, soil fertilization or foliar plus soil fertilization did not increase height growth but increased dry-weight increment by 40 to 50 percent over unfertilized seedlings.

———— **and Wilhite, L. P.**

1967. Operational summer planting of slash pine. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-80, 3 pp.

More than 1.3 million slash pine seedlings were planted throughout Florida and south Georgia during the summer of 1966. Overall survival as of February 1967 was 71 percent.

———— **and Woods, F. W.**

1967. The frequency and implications of intraspecific root-grafting in loblolly pine. Forest Sci. 13:226-239.

Studies were carried out in 27- to 83-year-old natural and planted *Pinus taeda* L. stands, on the Duke Forest near Durham, North Carolina, to determine: (1) the prevalence of intraspecific root-grafting; (2) rates of mineral transfer between trees and living stumps; and (3) growth and decay of living stumps. Iodine-131 tracer techniques and field surveys were used to study the prevalence of root-grafting. Rates of mineral translocation were determined by radioactive phosphorus. Intraspecific root-grafting was common but less prevalent than for most species. Of 16 trees inoculated with I-131, 4 were root-grafted to single neighboring trees. Only 7.6 percent of 2,054 stumps, or approximately 4 per acre, were grafted to living trees. Initial rates of P-32 translocation, from stump to donor tree varied from 0.10 to 5.06 feet per hour, with rates of 1 to 3 feet per hour most common. Water stress appeared to be necessary for P-32 translocation through many root-grafts. Xylem formed on living stumps was composed of very short (0.4 to 1.5 mm.) disoriented tracheids which probably aided lateral movement of minerals and water.

Shaw, S. P., and Ripley, T. H.
1966. Managing the forest for sustained yield of woody browse for deer. Soc. Amer. Forest. Proc. 1965: 229-233.

Results of deer range sampling in six eastern National Forests show how timber management activities can be programed to maintain a continuous supply of woody browse within the average home range of a deer.

Sluder, E. R.
1964. Quality of yellow-poplar planting stock varies by mother tree and seedbed density. USDA Forest Serv. Tree Planters' Notes 65: 16-19.

Seedling size affects survival of planted yellow-poplar. Little is known, however, of the effect of root pruning on survival of yellow-poplar seedlings or of the effect of maternal parent on survival and phenotype of progeny groups. Such information would be valuable to those wishing to plant yellow-poplar for forestry purposes. This study showed that 1-0 seedling size of yellow-poplar varied with nursery bed density and by maternal parent tree. Higher bed densities produced too many small seedlings. Optimum density for this study was 25 to 30 seedlings per square foot. Some progeny groups had greater percentages of small seedlings than did others. First-year survival of planted seedlings also varied by progeny group, but not by root-pruning treatment. As an aid to nursery practices and tree improvement, evaluation of progeny will be made when the trees are larger.

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1964. White oak direct seeding in the North Carolina Piedmont. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-29, 2 pp.

Depth of planting was the most important factor studied in a survival test of direct seeded white oak. The best treatment, fall planting acorns 1 inch deep with screened protection, resulted in 67 percent seedling establishment. On the other hand, surface-sown seedlings did not survive regardless of season of planting or protection.

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1965. Direct seeding scarlet oak in the North Carolina mountains. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-41, 2 pp.

The best treatment for direct seeded scarlet oak was to plant acorns 2 inches deep with a screen cover. Surface-planted seed failed to survive.

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1966. Hand-pollinate yellow-poplar without climbing. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-54, 7 pp.

Limbs are shot from mature trees, and dormant twigs with flower buds are grafted onto growing seedling rootstocks. Flowers are pollinated on the grafts as they bloom.

——— **and Rodenbach, R. C.**
1964. Yellow-poplar direct seeding in the North Carolina Piedmont. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-25, 2 pp.

Screen protection, depth of seeding, and season of sowing were all shown to be important in a yellow-poplar direct seeding study in the Carolina Piedmont. The best treatment combination was spring planting the seed ⅛ inch in the ground with screen protection.

Smith, R. H., and Kowal, R. J.

1968. Attack of the black turpentine beetle on roots of slash pine. J. Econ. Entomol. 61: 1430-1432.

Dendroctonus terebrans (Olivier) attacks the roots of slash pine soon after its first attacks on the trunk; these root attacks correspond closely in number and development to those on the trunk. Initial contact is made near the root origin. Subsequent damage is concentrated in this region at first but later extends several feet on the lateral roots. Such root damage may actually be responsible for the death of those trees which apparently die from a relatively small number of trunk attacks.

Smith, W. R.

1964. Forest products to please the consumer. Auburn Forest. Forum Proc. 1963: 61-69.

The new home builder is often persuaded to build a structure incorporating everything but wood. Even when wood is used it is often mishandled, inviting the use of competitive materials. Wood must be designed as a ready-to-use material to remain competitive. Forestry oriented people should consciously profess virtues of wood through its ultimate product use. Specific knowledge of wood use should include wood dimensional properties, decay hazards, fire behavior, overlay benefits, laminating, sandwich construction, and chemical derivatives.

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1964. Research in wood harvesting systems for fiber products. Amer. Pulpwood Assoc. Tech. Pap. 63-65(0.6): 24-26.

Research in pulpwood harvesting has been restricted mainly to equipment development. Pulpwood raw material costs are higher than those for competing plastics and foils. Large mechanical wood harvesting machines are discussed and their restrictions noted. Other systems of logging are discussed. Wheel tractor machines may be more advantageous in the South than other systems. Forest research in engineering at four U. S. laboratories is briefly discussed. Pipeline movement of chips may be feasible providing continuous chip infeed is maintained. This method, coupled with greater use of tree at site, may be necessary to keep pulpwood competitive as a sheet material.

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1965. Selecting furniture. U. S. Dep. Agr. Yearbook 1965: 84-87.

Major furniture wood species are described, with a caution about cross grain and general table sturdiness; also discussed are joint construction, glued parts, hardware used, plywood construction, and furniture finishing.

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1966. Hardwood flooring in rehabilitation. Building Res. 3(6): 47-50.

Floor leveling systems and prefinished panelized flooring were developed and tested by Forest Service scientists in cooperation with industry. Many of these products were demonstrated in a New York City Urban Rehabilitation Project.

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1967. Simplified guidelines to hardwood lumber grading. USDA Forest Serv. Southeast. Forest Exp. Sta., 26 pp.

A simplified system for teaching a novice the fundamentals of measuring and grading hardwood factory lumber. It does not cover many of the exceptions and other fine points that must be learned from the Standard Rules to become an accomplished inspector. It is primarily for people who need a working acquaintance with grading procedures.

Smith, W. R.

1967. Wood for the campfire and the fireplace. U. S. Dep. Agr. Yearbo 1967: 95-98.

Firewood varies by species with respect to fuel value, tenden to smoke, ease of burning, ease of splitting, and other characte istics. This article classifies wood species by these characteristi and provides helpful information on fire building, types of cam fires, protection, and suggests chemicals that will provide differe colors in burning wood.

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1968. Hardwoods in the Southeast—opportunities for the seventie Cross Ties 49(12): 53-59.

With particular reference to the production of hardwood cros ties in the five Southeastern States, this article presents estimate of hardwood sawtimber inventory for 1968 by log grades, estimate of net growth and removal, trends in cross tie requirements, an proposes an automated method for the production of treated cros ties from laminated wood.

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1968. Marketing research at the Southeastern Forest Experiment Station. South. Lumberman 217(2704): 108-110.

The forest products marketing research program is directe toward improving the markets for wood used in construction repair, and maintenance.

Snow, G. A., and Roncadori, R. W.

1965. Oak leaf age and susceptibility to *Cronartium fusiforme*. U. S Dep. Agr. Plant Dis. Rep. 49: 972-975.

Leaves of water oak, an important alternate host of the fusiform rust fungus, were used to determine the ages at which oak leaves are susceptible to rust infection. In general, leaves are resistant to infection after they are 2 weeks old, and as they mature become increasingly resistant.

Snyder, E. B., and Squillace, A. E.

1966. Cone and seed yields from controlled breeding of southern pines South. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SO-22, 7 pp

Over a 10-year period, survival of cones from controlled cross-pollinations was less than 40 percent, and seed yields per cone averaged about half those from wind-pollinations. Self-pollinations produced about 15 percent as much seed as cross-pollinations

——— **Squillace, A. E., and Hamaker, J. M.**

1966. Pigment inheritance in slash pine seedlings. Eighth South. Conf Forest Tree Impr. Proc. 1965: 77-85.

Three groups of characters in wind- and controlled-pollinated progenies of slash pine were studied: chlorosis in 2½-month-old seedlings, cotyledon chlorophyll defectives, and hypocotyl anthocyanin variants.

Sorensen, F. C.

1964. Inheritance of needle and bud characteristics of slash pine. Silvae Genet. 13: 109-114.

The following characteristics were shown to be strongly inherited: needle length, needle bundle volume, fascicle, sheath length, needle divergence, and bud scale length.

Southeastern Forest Experiment Station

1964. Annual report for 1963. USDA Forest Serv. Southeast. Forest Exp. Sta., 74 pp.

Highlights of the Station's research results.

Southeastern Forest Experiment Station

1964. Improvements at Coweeta. USDA Forest Serv. Southeast. Forest Exp. Sta., 17 pp.

Illustrated brochure describes construction of new hydrology-meteorology workshop, offices, dwelling quarters, storage sheds; also repair of roads, trails, weirs, and the treatment of watersheds under Accelerated Public Works Program.

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1965. Forage, timber, and wildlife research in the Georgia flatwoods. USDA Forest Serv. Southeast. Forest Exp. Sta., 13 pp.

Describes three decades of cooperative work carried on by the Georgia Coastal Plain Experiment Station, the U. S. Department of Agriculture's Forest Service, and Agricultural Research Service at Tifton, Georgia. Improvements in experimental beef herds and native forage on forest ranges are outlined, as well as progress in timber and pulpwood raising. New investigations in wildlife show that quail and other game can be much increased by scientific management of game food plants and habitat.

Southwell, B. L., and Hughes, R. H.

1965. Beef cattle management practices for wiregrass-pine ranges of Georgia. Ga. Agr. Exp. Sta. Bull. N.S. 129, 26 pp.

Spring-summer grazing treatments involving unsupplemented forest range, improved pasture and combinations of the two were tested over a 6-year period. Calf production from these treatments ranged from 325 to 376 pounds per cow per year. Other management practices—burned range, ample fall-winter feed, and some Brahman blood in cows—contributed to the success of treatments.

——— **and Hughes, R. H.**

1967. Beef cattle management practices for burned and unburned pine-wiregrass ranges of Georgia. Univ. Ga. Coll. Agr. Exp. Sta. Res. Rep. 14, 19 pp.

Native wiregrass forage growing beneath developing slash pine plantations may be successfully used for cattle production if cows and their calves have free access to a limited acreage of improved pasture during the spring and summer and are fed hay off range during the fall and winter.

Speers, C. F.

1967. Pales weevil. USDA Forest Serv. Forest Pest Leafl. 104, 4 pp.

Importance, range, hosts, injury, description of stages, life history, control through management, and control with insecticides.

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1968. Balsam fir chalcid causes loss of Fraser fir seed. USDA Forest Serv. Tree Planters' Notes 19(2): 18-20.

In 1964 a chalcid, previously unreported in the Southern Appalachians, was discovered causing serious damage to seed of Fraser fir, *Abies fraseri* (Pursh) Poir. Specimens were identified as *Megastigmus specularis* Walley. In 1964, a poor crop year, insect-caused seed losses averaged 29 percent. In 1965, a good crop year, losses averaged 3.5 percent. The population of *M. specularis* probably remained constant for both years; therefore, the higher percentage of seed loss in the poor crop year resulted because fewer seeds were available for insect attack. Two parasites of *Megastigmus* were recovered.

Squillace, A. E.

1964. Finer pines aid turpentiners. South. Lumberman 209(2609): 95

Progress in the development of slash pines with high gum y and superiority in other desirable characteristics is summarize

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1966. Combining superior growth and timber quality with high g yield in slash pine. Eighth South. Conf. Forest Tree Impr. P 1965: 73-76.

Data show that high gum yield can be combined with supe growth and timber quality. A seed-production area and seve clonal orchards are being established with this objective.

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1966. Geographic variation in slash pine. Soc. Amer. Forest. Fo Sci. Monogr. 10, 56 pp.

Twelve morphological traits were studied in cones, seeds, foliage from the parents, and 13 morphological and physiologi traits were studied in the seedlings. Most traits showed appr able stand-to-stand variation. The patterns of stand variat differed among traits, but most were characterized by grad changes between one or more "highs" or "lows." Many of patterns contained a latitudinal gradient through Florida with trend reversal in the "north-central" area (extreme south Geor and north Florida).

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1966. Planning tree improvement research at Olustee. AT-FA J. 28(11-13.

Describes techniques, major accomplishments, and future w plans in developing high gum yielding and otherwise superi slash and longleaf pines.

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1966. Racial variation in slash pine as affected by climatic facto Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE- 10 pp.

Most slash pine traits show definite geographic patterns caus by environmental modification and genetic adaptation. The pa terns are usually characterized by gradients existing betwe extreme types located at fringes or within interior portions of t species range. A zone of optimum environment seems to occu within which native trees are phenotypically and genetically supe ior in growth rate to trees in less favorable environments.

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1967. Effectiveness of 400-foot isolation around a slash pine seed orchar J. Forest. 65: 823-824.

In an experiment designed to determine the effectiveness of 400-foot-wide isolation zone for a 5-acre seed orchard, all ma flowers within the orchard were removed prior to pollinatio Female cones borne the same year developed normally and pr duced normal yields of germinable seed. Isolation, therefore, wa not effective under these conditions. Studies designed to dete mine how much contamination occurs under normal conditions, wit a good pollen crop on seed orchard trees, are urgently needed.

Squillace, A. E.

1967. Selection of superior trees. Ninth South. Conf. Forest Tree Impr. Proc. 1967: 7-9.

Control of environmental effects in the stand in which selection is made is the key to effective mass selection. Selection should be made in plantations if the seed source is known to be suitable and if it was established from a mix of seed from many trees.

Lacking suitable plantations, the breeder should (1) select from the best wild stands available, from the standpoint of both superiority and uniformity of environmental factors; (2) adjust for environmental factors to the extent possible; (3) select and progeny test relatively large number of trees to permit heavy roguing after progeny testing; and (4) establish plantations from progenies of large numbers of selections, to be used as a base for the next cycle of selection.

——— **and Fisher, G. S.**

1966. Evidences of the inheritance of turpentine composition in slash pine. *In* Joint proceedings second genetics workshop of the Society of American Foresters and the seventh Lake States forest tree improvement conference 1965. North Central Forest Exp. Sta., U. S. Forest Serv. Res. Pap. NC-6, pp. 53-60.

Individual tree differences and racial variation occur in the content of some gum constituents of slash pine. These differences are strongly inherited, and reveal opportunities to breed for specific gum composition, to capitalize on geographic variation in commercial gum operations, and to develop a useful tool in pine genetics research.

——— **and Franklin, E. C.**

1968. "Instant" progeny tests. Forest Farmer 27(13): 8-9.

Slash pine progenies can be assessed for gum-yielding ability at juvenile ages, 7 to 8 years earlier than with previous methods. Seeds are sown in peat pots, outplanted shortly after germination at a spacing of 1½ by 3 feet, and given intensive cultural treatment. At 2½ years from seed, the trees average about 9 feet tall and are evaluated for gum-yielding ability by a miniature chipping technique.

——— **and Gansel, C. R.**

1968. Assessing the potential oleoresin yields of slash pine progenies at juvenile ages. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Note SE-95, 4 pp.

The potential oleoresin yields of slash pine progenies can be assessed at juvenile ages, 7 to 8 years earlier than with previous methods. Seeds are sown in peat pots, outplanted shortly after germination at a spacing of 1½ by 3 feet, and given intensive cultural treatment. At 2½ years from seed, when the trees average about 9 feet tall, their potential yields are evaluated by a miniature chipping technique.

——— **and Harrington, T. A.**

1968. Olustee's high-yielders produce 487 barrels per crop for 4 years. AT-FA J. 30(8): 9-10. Also, with title Olustee's high-yielders produces 487 bbls. pine gum per crop for four straight years, in Nav. Stores Rev. 77(12): 4-5.

When worked by commercial methods over a 4-year period, offspring of high-yielding slash pines produced twice the normal amounts of gum. The data confirm earlier results from microchipping. Further, gum yields from most of these high-yielding families do not show the usual drop in production commonly associated with the third and fourth year of work; instead, their yields continue to increase.

Stegall, W. A., Jr.

1966. Fruiting of *Fusarium lateritium pini* on naturally infected p pitch cankers. U. S. Dep. Agr. Plant Dis. Rep. 50: 476-477.

Fusarium lateritium pini, the causal agent of the pitch can disease of certain species of hard pines, has been known for seve years. The manner in which it is disseminated, however, has b obscured by the apparent lack of fruiting on the surfaces cankers. Recently, inconspicuous sporodochia were found on surfaces of pitch cankers on Virginia and shortleaf pines grow near Asheville, North Carolina. Mass and single spore cultu obtained from these structures were used to make 40 inoculati in healthy Virginia pines. Typical pitch cankers resulted from inoculations.

Steinbeck, Klaus

1966. Site, height, and mineral nutrient content relations of Scotch pi provenances. Silvae Genet. 15: 42-49.

Describes the effect of widely divergent seedlot origin and s on the foliar levels of 12 minerals. Demonstrates significa among-seedlot differences in the accumulation of foliar N, P, N Mg, and B and relates nutrient content to differences in curre internode growth. Emphasizes efficiency of nutrient utilizati and proposes pathways through which genetic differences may expressed in growth.

——— **and Kormanik, P. P.**

1968. First-year root system development of two clones of yellow-popla Ga. Forest Res. Counc. Res. Pap. 55, 4 pp.

A fast-growing clone of yellow-poplar was compared with slow-growing one after a growing season in the field. The fa grower out-performed its partner in all measured characteristi above as well as below ground.

——— **and McAlpine, R. G.**

1966. Inter- and intra-specific differences in the root respiration rat of four hardwood species. Forest Sci. 12: 473-476.

The respiration rates of root tips from clonal propagules yellow-poplar, red maple, weeping willow, and black willow we determined manometrically. One clone of black willow differe significantly from the other clones in that species, but no signif-cant intra-specific differences were found among randomly selecte clones of the other three species. The root respiration rates red maple and weeping willow did not differ significantly; a other species showed significant differences.

——— **May, J. T., and McCreery, R. A.**

1966. Growth and needle color abnormalities of slash pine seedling caused by nutrient treatments. Ga. Forest Res. Counc. Res. Pap. 38 9 pp.

Slash pine seedlings in both the greenhouse and the nurser were subjected to various nutrient treatments to establish definitiv relationships between mineral nutrition and conditions conduciv to foliage discolorations and to abnormal growth patterns.

——— **and Porterfield, E. J.**

1967. Short-term storage of yellow-poplar softwood cuttings. Southeast Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-71, 4 pp.

Yellow-poplar softwood cuttings were stored in plastic bags at 41° F. for 0, 3, 5, 7, and 15 days. After storage the cuttings were rooted in a mist bed. There was no significant decrease in rooting capacity with storage. Field collection and shipment from distant points of this succulent tissue will present no problems if the recommendations for cutting and storing are followed.

Stern, E. G.
1964. Nails and spikes in hickory. USDA Forest Serv. Southeast. Forest Exp. Sta. Hickory Task Force Rep. 9, 37 pp.

Slender nails cause less splitting and may be driven without predrilling, especially when nailing machines are used. High-carbon steel nails have 75 percent greater nail withdrawal in dry hickory than bright low-carbon nails. Helically threaded nails offer higher holding power in both green and dry hickory. When predrilling, holes should be 10 and 20 percent smaller in diameter for bright low-carbon and hardened high-carbon nails, respectively. Tables of nail sizes for optimum performance by use are given.

Stewart, J. T.
1965. Regenerating loblolly pine with four seed trees. Va. Forests 20(2):14-15, 26, 28.

Acceptable loblolly pine regeneration was obtained from released seed trees selected in accordance with the Virginia Seed Tree Law. Three well-stocked pine stands and one pine-hardwood stand were obtained with no special site preparation or hardwood control. The seed crop record for 1956-1957 demonstrated that a combination of unfavorable weather can greatly reduce cone crop. Until more is known of the effect of release cutting date on seed production, it is safest to complete preharvest release cuttings in the dormant season, or not later than the first of May to get increased seedfall within 3 calendar years.

Stubbs, Jack
1967. Hardwood type-site relationships on the coastal plain. 1966 Symp. Hardwoods of the Piedmont & Coastal Plain Proc., Ga. Forest Res. Counc., Macon, Ga., pp. 10-12.

The lower, middle, and upper portions of the southeastern coastal plain are of widely varying geologic age, ranging from a Pleistocene erosion surface in lower coastal plain flatwoods, to a Cretaceous land surface in upper coastal plain sandhills. These age differences are evident in the degree of drainage system development, a critical factor in determining the nature and extent of hardwood site-types. All the commercial hardwood forest in the southeastern coastal plain exists on lands that are too wet, in their pristine condition, for agriculture. All sorts of moisture regimes and hydrologic conditions combined with great soil diversity have resulted in many kinds of hardwood sites, some of them very different. Furthermore, this region is a veritable museum of hardwood species; at least 70 with some commercial value can be listed. The net result is a broad variety of forest types.

Coastal plain hardwood site-types can be logically classified according to landform or physiographic position, giving special emphasis to drainage conditions. In most soil-site studies for hardwoods, topographic position has predicted site better than all the soil variables combined. Characteristic major hardwood site-types of the coastal plain include: (1) swamps dominated by tupelo gums and baldcypress; (2) upland ponds with swamp tupelo and pondcypress; (3) Carolina Bays which may contain white and red bay, also red maple, with tupelo and cypress; (4) wet flats, having stands wherein loblolly pine is often mixed with sweetgum, various oaks and hickories, and many other species; (5) river and creek bottomlands containing sweetgum, oaks, ashes, hickories, beech, and yellow-poplar. Productivity in these site-types ranges from poor to absolutely spectacular, and these better sites present the South's most glittering forest management opportunity.

Surany, Paul

1967. Basic functions in *Bacillus thuringiensis* affecting its mode pathogenesis, pp. 247-248. *In* Insect pathology and microbial co trol. Int. Colloq. Insect Pathol. & Microbial Contr. Proc., T Netherlands, 1966. Amsterdam: North-Holland Publishing Co.

In certain groups of *Bacillus thuringiensis*, sporogenesis m be preceded or substituted by gonidigenesis, the gonidia then se ing as the point of departure for a range of cellular transform tions and subsequent mutations. Gonidia should be regarded constituting a distinct class of etiological entity, endowed wi functions and pathogenic capabilities apart from and beyond th of the typical cellular form of *B. thuringiensis*. Populations of *thuringiensis* selected for their stabilized, dominantly gonidifero character were induced to regain the crystalliferous character the species. Such variants also tended toward giantism, with r sultant isolates capable of producing remarkably large tox crystalloids in the complete absence of spores.

Swank, W. T.

1968. The influence of rainfall interception on streamflow. Hydro Water Resources Manage. Conf. Proc. Clemson Univ. Water R sources Res. Inst. Rep. 4, pp. 101-112.

Interception loss is a major component of the water balance forested lands in the Southeast. Experiments at the Cowee Hydrologic Laboratory in western North Carolina have shown th appreciable reductions in streamflow occurred 10 years after watershed was converted from mature mixed hardwoods to eastern white pine plantation. Water yield reductions are di cussed in relation to interception loss. Examination of differenc in interception loss between southern pine species and hardwoo suggests that conversion to pine may substantially reduce strea flow.

——— **and Miner, N. H.**

1968. Conversion of hardwood-covered watersheds to white pine reduc water yield. Water Resources Res. 4: 947-954.

Mixed mature hardwoods were cleared from two Southern Appalachian experimental watersheds, and the areas were plante with eastern white pine in 1956-1957. Once the pine crowns bega to close, streamflow steadily declined at a rate of 1 to 2 inche per year. By 1967, water yield was 3.7 inches less from 10-year-old pine stand on a south-facing watershed than expecte water yield from the original hardwood forest. Most of the wate yield reduction occurred during the dormant season and was attributed mainly to greater interception loss from white pin than from hardwoods. Because interception differences increas as white pine matures, an even greater reduction in streamflow i expected.

Swindel, B. F.

1968. On the bias of some least-squares estimators of variance in general linear model. Biometrika 55(2): 313-316.

This paper treats some of the problems of least-squares analyse of a general regression model when an incorrect assumption i made regarding the error covariances. Bounds on the bias of th least-squares estimators of the variance of arbitrary linear functions of the regression coefficients for arbitrary design matrice of full rank are obtained.

Talhelm, D. R.

1967. Factors influencing the length of stay of campers in the Waterloo Recreation Area, Michigan. Mich. Univ., Mich. Forest. Outdoor Recreation 1, 10 pp.

A statistical analysis of about 9,500 campers' permits from the Waterloo Recreation Area of southeastern Michigan revealed two distinct relationships between visitor characteristics and length of stay: (1) The farther a camper was from home, the shorter was his length of stay; and (2) a camper's stay tended to end on Sunday, regardless of the day he came to the campground. Other findings were less distinct. Campers from larger metropolitan areas tended to stay longer than campers from less densely populated areas the same distance away. The length of stay tended to increase with party size. Campers with boats tended to stay slightly longer. Finally, the type of camp (tent, trailer, etc.) showed little relationship to length of stay.

Taras, M. A.

1967. Moisture content variation of finished and partially finished wood in homes in the Southeast. Forest Prod. J. 17(8): 60-63.

Seasonal variations in the moisture content of unfinished, partially finished, and completely finished wood are given for different parts of the home and different geographical locations in the Southeast. Air conditioning helps create a rather uniform equilibrium moisture content condition throughout the year with moisture content variations of only 2 to 3 percent occurring between seasons.

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1967. Weight scaling: its past-present-future. Wood Meas. Conf. Proc. 1967, Univ. Toronto Tech. Rep. 7:143-156.

History of weight scaling in the southern part of the United States is presented. Past work on development of prediction equations and weight equivalents is reviewed. Weight equivalents being used currently and future needs for the improvement of weight scaling are discussed briefly.

——— **and Saucier, J. R.**

1967. Influence of extractives on specific gravity of southern pine. Forest Prod. J. 17(9): 97-99.

The results of this research should be most helpful in such fields as estimating pulp yields and in research on tree improvement, genetics, and environmental factors. In analyses of specific gravity values determined on both extracted and unextracted increment cores, the authors found that the use of unextracted cores results in a 6.0 to 7.5 percent overestimate of wood substance. They present equations for each of the four major southern pine species that can be used to predict the specific gravity values of extracted material from values determined on unextracted material.

——— **and Saucier, J. R.**

1968. Wood density surveys of the minor species of yellow pine in the Eastern United States. Part I—spruce pine (*Pinus glabra* Walt.). Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-34, 15 pp.

Spruce pine (*Pinus glabra* Walt.) was sampled over its entire range at 35 different locations. Specific gravity was determined on increment cores in an extracted and unextracted condition. Tree/increment core specific gravity relations were examined, and equations for predicting tree specific gravity developed. Geographic variation in the specific gravity of spruce pine is discussed.

Taylor, C. C.

1966. Who is the small forest landowner? Forest Farmer 25(6): 8- 14, 16.

Under current definitions, some "small" owners are quite larg some categories are unable to practice forestry, and some ar opposed to timber production. Author advocates fresh look at ol problem.

Taylor, D. F.

1964. Weather's role in prescribed burning. Va. Forests 19(2): 10-13

The importance of specific weather elements in the timing an proper conduct of prescribed burning.

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1966. Fire-weather spring 1966. Ga. Forest Res. Counc. Res. Pap. 43 16 pp.

A discussion of the climatology and synoptic weather associate with the fire experience in the southeastern states during the sprin of 1966, together with three case histories of special meteorologica importance.

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1967. Future of the National Fire Danger Rating System. 27th Annu. South. States Forest Fire Contr. Conf. & South. States Inform. & Educ. Meeting 1966: 87-91.

The future of the National Fire Danger Rating System depends upon advances being made in the development and testing of the widely used spread phase and upon basic research now being conducted in physics, chemistry, meteorology, and forestry. The results of this research will, hopefully, result in the derivation of an improved spread index and additional indexes. Until such time as this work is completed, the fire control manager has an important role to play in the testing of new indexes and providing accurate fire records and fire danger observations.

——— **Ryan, P. W., and Pachence, A. M.**

1964. An analysis of 1963 forest fires and fire danger in Georgia. Ga. Forest Res. Counc. Res. Pap. 25, 56 pp.

Graphic and tabular presentation of fire statistics by districts with indication of trends. Short introduction to National Fire Danger Rating System.

——— **and Wendel, G. W.**

1964. Stamper Tract prescribed burn. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-14, 12 pp.

Case history of a successful prescribed burn in the pocosin types of North Carolina.

——— **and Williams, D. T.**

1967. Meteorological conditions of the Hellgate Fire. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-29, 12 pp.

High temperatures, low humidities, and strong winds, resulting in a condition of EXTREME fire danger, were present during the Hellgate Fire. Convection was favored by the absolute instability of the airmass and was triggered by the approach and passage of a pressure trough line.

Taylor, D. F., and Williams, D. T.

1968. Severe storm features of a wildfire. Agr. Meteorol. 5: 311-318.

The Hellgate Fire occurred in the warm sector of an extratropical cyclone system in which high temperatures, low humidities, and strong winds produced a condition of *extreme* fire danger. The airmass was absolutely unstable from the surface to 5,000 ft. and was favorable for convection to 11,000 ft. Convection appears to have been triggered by the approach of a pressure trough line embedded in the warm sector. Large-scale negative divergence and cyclonic vorticity of the surface wind field appear to have contributed to the vertical development of the fire.

The warm sector location, the pressure trough line, the fields of divergence and vorticity, and the instability of the airmass were similar to conditions which produce severe thunderstorms and tornadoes. The pressure trough line, the fire itself, and the fire whirlwinds were analogous, respectively, to an instability line, a severe thunderstorm, and tornadoes.

The similarity of the meteorological parameters of the Hellgate Fire to those producing severe thunderstorms and tornadoes suggests that methods for forecasting severe storms could be used in forecasting unusual fire behavior.

Thomas, H. A.

1968. A description of the pupa of the pales weevil, *Hylobius pales*, and a method for identifying its sex. Can. Entomol. 100: 434-437.

The pupal stage of the pales weevil, *Hylobius pales* (Herbst), is described with notes on distinguishing it from the pupa of *Pachylobius picivorus* Germar, together with a means for sexing pales weevil pupae.

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1968. Distribution of the balsam woolly aphid predator, *Leucopis obscura*, in Maine. Ann. Entomol. Soc. Amer. 61: 1344-1346.

The predator, *Leucopis obscura* Hal., was introduced into North America at New Brunswick, Canada, in 1933, about 50 miles from the eastern border of Maine. Its subsequent invasion and present distribution in Maine well over the area occupied by its host, *Adelges piceae* (Ratz.), is reported.

———— **Darst, P. H., and Farrier, M. H.**

1967. Acarine associates of the pales weevil, *Hylobius pales* (Coleoptera: Curculionidae). Fla. Entomol. 50: 263-266.

Pales weevils, *Hylobius pales* (Hbst.), from three locations in North Carolina and one in Florida were examined for mites. The mites found on the weevils were *Histiogaster anops*, *Digamasellus* sp., *Histiostoma* sp., and a new species of Podapolipodidae. Twenty-three percent of the weevils examined were infested with mites which were chiefly hypopi. Weevil larvae and pupae were also found to be infested primarily by *Histiostoma* sp.

Thompson, J. H., Cowling, E. B., and Ross, E. W.

1968. Changes in moisture content and color of the cambial zone in bolts of pine stemwood during colonization by *Fomes annosus*. Can. J. Bot. 46: 1533-1537.

Two isolates of *Fomes annosus* were found to grow with equal rapidity (about 12 mm. per day at 24° C.) through, or over, a split surface of fresh sapwood in bolts cut from pine stems, and at a similar rate over the surface of malt-extract agar.

As the fungus progressed through the bolts longitudinally, marked browning of the cambial zone was observed at whatever distance from the inoculated end of the bolts the fungus could be isolated. Also, as much as 13 percent of the water present was moved from infected portions of inoculated bolts to portions not yet colonized by the fungus.

Trousdell, K. B., and Langdon, O. G.

1967. Disking and prescribed burning for loblolly pine regeneration. J. Forest. 65: 548-551.

Disking and three summer prescribed burning series were compared in the Virginia coastal plain on the basis of cost and effectiveness in regenerating loblolly pine (*Pinus taeda* L.). Disking cost about four times more than the longest and most expensive series of summer prescribed burns. Seedling stocking was adequate for all site preparation treatments at 2 years, but significantly fewer seed were needed to produce one seedling in the three-summer-burn treatment than in any of the other treatments. The same treatment was also best in holding down crown coverage and size of the small hardwood competition. None of the treatments appeared to have a lasting effect on the shrub component of the understory vegetation.

———— **Williams, W. C., and Nelson, T. C.**

1965. Damage to recently thinned loblolly pine stands by Hurricane Donna. J. Forest. 63: 96-100.

Over 99 percent of damaged trees were root displaced or blown down. Stem breakage was insignificant. Damage was more severe on soils having moderately coarse-textured profiles than on soils with finer textured profiles. It was most severe where restrictive layers occurred within the profile that tended to retard root and water penetration.

VanHaverbeke, D. F., and Barber, J. C.

1964. Seed crop estimation in a loblolly pine seed production area. Ga. Forest Res. Counc. Res. Pap. 21, 5 pp.

Application of binocular counts of cones to loblolly pine seed production areas. Sample counts were made on 100 standing trees and 50 were cut to get exact cone counts. Data are presented on the accuracy of the binocular counts and estimates derived for total seed production from the area. Collecting cones from trees producing a stated minimum of cones is important. By restricting collections to trees that have some minimum number of cones, such as 100 or 200, the majority of the seed can be obtained from the area with appreciable reduction in collection costs.

———— **and Hunt, D. L.**

1964. Some seed-cone-tree relationships in a loblolly pine seed production area. Ga. Forest Res. Counc. Res. Pap. 22, 5 pp.

The relationships of number of cones per tree, seed size, cone size, and various characteristics of the tree. Though several significant correlations are found, there are no strong relationships among the seed-cone-tree characteristics examined. The results strongly imply that the ability of the tree to produce cones is an inheritable characteristic.

Varnell, R. J., and Bennett, F. A.

1966. Direct seeding on flatwood sites. Forest Farmer 25(5): 8-9, 21-22.

Repellent-treated seed of slash pine (*Pinus elliottii* Engelm. var. *elliottii*) were surface sown following three site treatments under two levels of shade on each of six dates. After 1 year, average germination on protected plots was 56 percent and average seedling establishment was 40 percent for March, the optimum time for sowing according to this study.

Varnell, R. J., Squillace, A. E., and Bengtson, G. W.

1967. Variation and heritability of fruitfulness in slash pine. Silvae Genet. 16: 125-128.

Large variation was observed in female flowers and cone production in three slash pine plantations in northeastern Florida. Broad-sense heritabilities of 0.50 for cone yields in 14- to 17-year-old rooted cuttings, and 0.49 for flower production in 4- to 6-year-old airlayered propagules, indicated moderate genetic control of fruitfulness. A narrow-sense heritability of 0.13 for cone yields in 16-year-old progenies indicated a low additive genetic component. An appreciable amount of nonadditive genetic variance was suggested by the large difference between the narrow-sense heritability and the broad-sense heritabilities and by the pattern of variation in flower and cone production.

Vick, C. B.

1965. Drying-rate curves for one-inch yellow-poplar lumber in low-temperature forced-air dryers. Forest Prod. J. 15(12): 500-504.

A series of drying-rate curves were developed for 1-inch yellow-poplar sapwood and heartwood lumber that can be used to estimate drying time from the green condition to 18 percent moisture content.

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1965. Forced air drying sweet gum furniture billets in solid stacks. Forest Prod. J. 15(3): 121.

Loads dried at 100° F. and 120°, 10 and 8 percent equilibrium moisture content, respectively, dried in less than 9 days to 18 percent m.c. Samples were almost free of degrade, and more severe drying conditions could probably be used.

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1968. Commercial forced-air drying of unstickered hardwood furniture rounds. Forest Prod. J. 18(7): 46-48.

Drying rate, degrade, and moisture content uniformity tests were run for solid-stacked, 2-inch-diameter hardwood furniture rounds in a special commercial forced-air dryer. Results from these tests were compared with those obtained from two exploratory tests under similar temperature and humidity conditions, but different air velocities.

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1968. Low-temperature drying of 1-inch sweetgum. Forest Prod. J. 18(4): 29-32.

Groups of drying-rate curves, and data on degrade and moisture content uniformity, have been developed for 1-inch sap sweetgum lumber at low-temperature, forced-air drying conditions. Actual drying rates were determined from moisture content sample boards that were dried at constant temperatures of 80°, 90°, 100°, 110°, and 120° F.; 10 percent equilibrium moisture content; and air velocity at 550 feet per minute. From these data, drying rates were calculated at the same temperature series and assumed EMC conditions of 6, 14, and 18 percent. The calculated drying rates were accurate in predicting drying time to within one-half to one day of actual drying time. This was equivalent to a maximum difference of 2.0 percent in actual and predicted final moisture content.

Degrade did not exceed $1.49 per thousand board feet in any tests at 10 percent EMC. Moisture content uniformity was good—standard deviations of moisture content ranged between 0.7 and 4.0 percent.

Vick, C. B., Gaby, L. I., and Baechler, R. H.

1967. Eleventh year service report . . . treatment of hardwood fence posts by the double-diffusion process. Forest Prod. J. 17(12): 33-35.

In 1955, more than 1,000 treated and untreated control fence posts of several native hardwood species were installed at an exposure test site near Athens, Georgia. The project was designed to test the effectiveness of a zinc salt preservative treatment applied by the relatively new, non-pressure double-diffusion process. This is the first service-life report to be issued on the durability of hardwood species treated by this method. Results are very encouraging, and recommendations have been proposed for further improvement in chemical retention, penetration, and toxicity.

Waggoner, P. E., and Hewlett, J. D.

1965. Test of a transpiration inhibitor on a forested watershed. Water Resources Res. 1: 391-396.

In an attempt to reduce transpiration from forested watersheds, two helicopter sprayings of 50 pounds of glyceryl half-ester of decenyl-succinic acid in water produced little acid deposit on undersides of leaves, no clear evidence of stomatal closure, and no significant increase in streamflow.

Webb, C. D.

1965. Variation in the wood of sweetgum. Forest Farmer 24(12): 9, 16-18.

A summary of a doctoral research project in which specific gravity, fiber length, and interlocked grain were investigated in 225 trees growing in the South Atlantic states. All three wood properties varied significantly within trees and among trees growing together in the same stand. The report makes the assumption that an appreciable part of the variation among trees is caused by hereditary differences that can be used in a breeding program, and advocates breeding sweetgum to improve form, bole quality, and growth rate as well as to increase fiber length and specific gravity but to reduce interlocked grain.

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1966. Improvement of sweetgum. Eighth South. Conf. Forest Tree Impr. Proc. 1965: 45-49.

Sweetgum, one of the most valuable southern hardwoods, has flowering, seeding, and planting characteristics that should facilitate the application of tree improvement to the species. Applied breeding offers a means of improving the growth efficiency of the species as well as the uniformity of the wood.

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1967. Interlocked grain in *Liquidambar styraciflua* L. XIV. IUFRO-Congr. Proc. Vol. IX (Sect. 41 + WG 22/41) Munich, 1967: 398-412.

Investigations of *Liquidambar styraciflua* showed that interlocked grain is a type of spiral grain in which the direction and angle of spiral change repeatedly among growth rings brought about by changes within a single ring with increasing height above the ground. There was a substantial range of variation in the severity of interlocked grain among trees growing in the same stand and among different stands. A few trees were found which were almost straight grained. Investigations of the orientation of perforation plates of vessel elements in the xylem suggested that the directions of pseudotransverse divisions in the cambium are associated with the direction of spiral in the xylem. Directional flow of growth regulators in the phloem and direction of mechanical pressures on the cambium were suggested as factors affecting the plane or orientation of pseudotransverse divisions in the cambium.

Webb, C. D.

1967. Seedling grade in hardwoods. USDA Forest Serv., S&PF, SA, Forest Nurserymen Conf. Proc. 1966: 11-15.

Seedling size, as reflected by root collar diameter, has a strong relationship to the success of hardwood plantations; seedlings with large root collars survive and grow better than seedlings with small root collars. The small seedlings can be eliminated by (1) controlling seedling density in the nursery through regulating sowing rate or through thinning; or (2) culling the smallest seedlings during the lifting and bundling process.

——— **and Barber, J. C.**

1966. Selection in slash pine brings marked improvement in diameter and and height growth plus rust resistance. Eighth South. Conf. Forest Tree Impr. Proc. 1965: 67-72.

Open-pollinated progeny tests at 5 and 8 years of age showed that selection produced substantial improvement in growth, resistance to fusiform rust, and volume per plot when compared with unimproved commercial check plots.

——— **and Darby, S. P.**

1967. Ideal nursery bed density for sweetgum seedlings. USDA Forest Serv. Tree Planters' Notes 18(2): 19-20.

Fifteen open-pollinated seedlots of sweetgum were sown in the nursery and thinned to densities approximating 10, 20, 30, and 40 seedlings per square foot. The best density for producing sweetgum seedlings lay between 15 and 25 seedlings per square foot. Within this range, we produced the maximum number of plantable seedlings per square foot of nursery bed, achieved good seed utilization, needed less time for culling unplantable seedlings, and produced seedlings that were small enough to plant easily, yet large enough to grow rapidly after planting.

——— **and Farmer, R. E., Jr.**

1968. Sycamore seed germination: the effects of provenance, stratification, temperature, and parent tree. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Note SE-100, 6 pp.

Various stratification periods and germination temperatures were applied to sycamore seed collected along the Chattahoochee River from north Georgia to west Florida. Results showed that percent and speed of germination were greater for seed from southern than from northern provenances. Percent and speed of germination increased as temperature increased. The interaction of provenance with stratification was significant only for germination speed. When seed were kept separate by parent tree, seed from isolated trees had poorer germination than did seed from trees growing near other sycamores.

——— **and Hunt, D. L.**

1965. Seed crop estimation in a slash pine seed production area. Ga. Forest Res. Counc. Res. Pap. 28, 5 pp.

Demonstrates accuracy of cone crop estimates based on binocular counts and the relation between number of cones per tree and cost of seed per pound. Wide variation found in cone production per tree and number of seed per pound.

——— **and Kraus, J. F.**

1966. The status of progeny testing clones in the Georgia Forestry Commission seed orchards. Ga. Forest Res. Counc. Res. Pap. 36, 4 pp.

Progeny testing loblolly and slash pine seed orchards is well under way. Oldest plantations have completed five growing seasons, but all of controlled pollinations have not yet been completed. A total of 101 acres of progeny test have been set out.

Webb, C. D., and McAlpine, R. G.

1967. New silvicultural methods. Ninth South. Conf. Forest Tree Impr. Proc. 1967: 38-40.

Recent trends in silviculture have embraced genetically improved seed, intensified cultural practices, and mechanical harvesting. Seedling production from pine seed orchards is accelerating rapidly, and these seedlings will receive more intensive cultural practices, including fertilization. The "silage" sycamore concept, to combat rising taxes and labor costs, proposes to use genetically improved strains of hardwoods, short rotations, mechanical harvesting, and coppice regeneration.

Webb, F. E., and Drooz, A. T.

1967. 41. Larch sawfly. *Pristiphora erichsonii* (HTG.), pp. 157-161. *In* A. G. Davidson and R. M. Prentice [ed.], Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. Dep. Forest & Rural Develop., Canada, Pub. 1180.

Contribution on forest pest problems by the Working Group on Forest Insects and Diseases, North American Forestry Commission, FAO.

Welch, R. L.

1965. Pulpwood prices in the Southeast, 1962-1964. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-46, 2 pp.

Average prices paid for rough pulpwood at delivery points, 1962 through 1964, and current average prices paid for chips.

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1966. Southern pulpwood production, 1965. Southeast. and South. Forest Exp. Sta., U. S. Forest Serv. Resource Bull. SE-7, 22 pp.

Production of round pulpwood and pulp chips from wood residues, by pine and hardwood species groups and by state; also, roundwood by county.

———

1967. Five-year trend in the price of pulpwood in the Southeast, 1962-1966. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-81, 2 pp.

The average prices paid for pine bolts increased almost 14 percent—from $16.55 to $18.80 between 1962 and 1966. The average prices paid for hardwood bolts increased 11 percent—from $13.40 to $14.90 during the same period. Both pine and hardwood chip prices show an overall increase during the 5 years.

———

1968. Forest statistics for the Northern Coastal Plain of South Carolina, 1968. Southeast. Forest Exp. Sta., U. S. Forest Serv. Resource Bull. SE-10, 35 pp.

The diversion of commercial forest land to other land uses has just about offset the addition of new forest land in the Northern Coastal Plain of South Carolina since 1958. Commercial forests still occupy about 4.7 million acres, or 63 percent of the total land area. Volumes of softwood and hardwood timber have increased by about 24 and 13 percent, respectively, reversing downward trends in volume between 1947 and 1958.

Wells, C. G.

1964. Fertilizing loblolly pine seedlings. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-26, 4 pp.

A variety of fertilizers applied in different forms and at various locations near loblolly pine seedlings at time of planting did not stimulate growth. Nutrient analyses on seedlings indicated the fertilizers did not provide readily available nitrogen, phosphorus, or potassium for the seedlings during the first 2 years in the field.

Vells, C. G.

1964. Slow growth of hardwood planted beneath a pine stand. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-22, 3 pp.

The slow growth of hardwood underplantings casts doubt upon the possible value of such plantings to improve the soil and produce a hardwood timber crop on poor upland Piedmont sites. Three years after planting, survival of northern red oak, yellow-poplar, and green ash was still approximately 95 percent, but only a few eastern redcedar survived. Height growth had ceased for all three hardwood species on the poorer soils and was slight for most trees on the better soils.

———

1965. Nutrient relationships between soils and needles of loblolly pine (*Pinus taeda*). Soil Sci. Soc. Amer. Proc. 29: 621-624.

Highly significant correlations were found between nutrients in the soil and needle content of 5-year-old loblolly pine for all seasons and needle age classes.

———

1968. Techniques and standards for foliar diagnosis of N deficiency in loblolly pine, pp. 72-76. *In* Forest fertilization theory and practice symposium 1967. Tenn. Val. Authority, Muscle Shoals, Ala.

Foliar analysis has value as a method for evaluating the N status of loblolly pine. In order to obtain comparable samples, the following standard sampling method is suggested: Collect needles in winter from the first growth flush of the previous spring from sunlit branches on the south side of the upper third of the crown.

Several reports in the literature indicate a relationship between foliar N and growth response to fertilization. In view of the relatively low N status of loblolly pine in the South, it was concluded N deficiency is widespread or that potential growth response to N fertilization does exist.

Accepting the implications that potential growth response to N does exist and does differ with environmental factors, work should proceed to further develop methods for defining and utilizing the growth response potential.

——— **and Davey, C. B.**

1966. Cation-exchange characteristics of forest floor materials. Soil Sci. Soc. Amer. Proc. 30: 399-402.

Pine, hardwood, and mixed pine-hardwood forest floor materials were studied. The effect of different saturation and replacement cations on cation-exchange capacity (CEC), the effect of pH of saturation solution on CEC, and the acid-base titration curves in relation to CEC were investigated. Source of material and degree of decomposition influenced quantitative, but not qualitative, aspects of chemical properties of the materials. Cation-exchange capacity and N content (meq./100 g.) were closely related; r = .892 is highly significant.

Werner, R. A.

1968. Fixation of introduced dyes in tissue of loblolly pine. Forest Sci. 14: 170-171.

Solutions of chloroform, butyl alcohol, and Craf IV are effective in preventing diffusion of dye from stained tissues of buds, needles, and stems of *Pinus taeda* L. into unstained tissues. It was found that these same fixatives would preserve the stained tissues for extended periods.

White, J. F., and Saucier, J. R.

1966. A comparison of the specific gravity of two slash pine varieties grown in south Florida. Tappi 49: 230-232.

Eleven-year-old typical slash pine (*Pinus elliottii* var. *elliottii*) produced a larger volume of wood of significantly greater density than South Florida slash pine (*P. elliottii* var. *densa*) of the same age grown on the same site.

———— **and Saucier, J. R.**

1966. The direct print copying of wood samples. Forest Prod. J. 16(6): 24.

Xerox copies furnish economical visual records of some wood samples in wood quality research.

Wilhite, L. P.

1964. Mechanical site preparation. (Abstr.) Assoc. South. Agr. Workers Proc. 1964: 164-165.

Methods, costs, and expected returns from various intensities of site preparation are illustrated and discussed. Three possibilities for increasing net returns from site preparation were explored: (1) higher survival at a given age; (2) more merchantable wood; (3) and a shortened rotation. The greatest opportunities for making site preparation ventures pay off are in greater total wood production and/or producing the same amount in a shorter period.

————

1966. Summer planting of slash pine shows promise in Florida. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Pap. SE-23, 8 pp.

Bare-rooted slash pine seedlings outplanted in the summers of 1963 and 1964 survived well, and in some instances grew faster than seedlings outplanted the following winter. Heretofore most planting has been done in winter. Planting during the summer rainy season in Florida would result in more even distribution of nursery and planting workloads.

———— **and Harrington, T. A.**

1965. Site preparation, pp. 22-31. *In* A guide to loblolly and slash pine plantation management in Southeastern USA. Ga. Forest Res. Counc. Rep. 14.

Economic considerations in site preparation, uses of fire, chemicals, and machinery, and some of the more promising techniques used in various sections of the loblolly and slash pine ranges.

———— **and Ripley, T. H.**

1965. Important understory plants of the slash-longleaf flatwoods. Ga. Forest Res. Counc. Res. Pap. 29, 4 pp. Also in AT-FA J. 27(11): 11-14.

One hundred plots were established in the slash-longleaf flatwoods of southeast Georgia and northeast Florida to determine disturbance succession of the understory and response of planted slash pines to increasing intensities of site preparation. This paper describes understory plant communities in the interval between clear cutting of the overstory and burning and harrowing of the sites in preparation for tree planting.

———— **and Sands, N. E.**

1965. Draining flatwoods ponds—a case history. Forest Farmer 24(5): 10-12.

A 3-mile drainage ditch, some 4 feet deep and 5 to 6 feet wide, was constructed through a wet, low-productive area in southeast Georgia, effectively draining about 200 acres. The following year, planted and natural slash pine stands were established in a cypress pond that previously had contained no pines. Tree measurements and cost and return estimates made 16 years later indicate that the drainage and pine establishment program was a success.

Villiams, D. T.

1967. A local kinematic method for computing vertical velocity from horizontal winds aloft data at a single station. Amer. Meteorol. Soc., Fifth Conf. Severe Local Storms Proc. 1967: 376-382.

The first two equations of motion are expanded to express vertical velocity in terms of the horizontal accelerations, vertical shears, horizontal spatial gradients, and ageostrophicity of the horizontal wind. The method is applied to serial winds aloft observations at a single station to obtain mean values of vertical velocity.

——— and Hauck, C. A.

1968. Fire behavior and the sea breeze front. (Abstr.) Amer. Meteorol. Soc. Bull. 49: 56.

Fire in a coastal forest exhibits unusual behavior when it is influenced by a sea breeze front. Its behavior is characterized by abrupt and seemingly capricious changes in direction and rate of spread and by increased intensity and convection. Two cases are presented to illustrate these features.

Effective fire control in coastal areas requires a knowledge of the sea breeze properties that affect fire behavior. Basic data on these properties have been gathered from a small-scale network of surface weather observing stations operated in coastal Georgia since March 1, 1967. Many passages of the sea breeze front have been documented, and the following properties have been noted:

(1) Occurrences range from late morning to late afternoon, but with most passages during the early afternoon. This is normally the time of greatest fire danger. (2) Motion is most often from east-southeast at speeds of 3 knots or less. The slow speed of the front causes it to influence a fire longer than conventional fronts, which move up to 10 times as fast. (3) Winds typically shift in 15 minutes time or less from westerly to southeasterly with increases in speed. The changes in the wind are directly responsible for the changes in direction and rate of spread of the fire. Oscillations and incomplete passages of the front may sometimes cause the wind to shift several times for a period of 2 hours or more. (4) The sea breeze front is a line of convergence, which may be sufficient to produce updraft velocities of a meter per second or more. These contribute to the increased intensity and convection of the fire. (5) Passages of the sea breeze front are frequent enough to present continuing problems in fire control, e.g., there were sea breeze frontal passages on 17 days in May 1967. Moreover it is indicated also that fire danger is generally greater on days with the sea breeze front than on days without it.

ilson, Porter, and Clements, R. W.

1968. Acid paste increases gum production. AT-FA J. 30(4): 6-7.

Gum farmer tells how the use of acid paste increased his gum production 100 barrels per crop in 1 year, and how only three laborers, working 5 days each week, can chip and treat four crops (40,000 faces) with the acid paste method.

orth, J. J. B., Ripperton, L. A., and Berry, C. R.

1967. Ozone variability in mountainous terrain. J. Geophys. Res. 72: 2063-2068.

Data from field studies have shown that the ozone concentrations in a complex environment do not exhibit the same mean values at mountaintop and valley sites. The occurrences of the maximum value for the two types of sites are approximately 180° out of phase, the mountaintop maximum occurring at night. Their relative concentrations often vary by a factor of 3 or 4. Ground level NO_2 concentrations were comparable to reported values. The NO/NO_2 ratio was approximately 0.65.

Yandle, D. O.

1968. Southern yellow pine tree overruns and lumber width distributions. Southeast. Forest Exp. Sta., U.S.D.A. Forest Serv. Res. Pap. SE-41, 12 pp.

This paper presents tree overruns and the distribution of rough-green lumber, by lumber grades and board widths, from trees graded by the Forest Service standard tree grades for southern pine. The data were collected from southwide lumber recovery studies that utilized loblolly, shortleaf, pond, longleaf, and slash pine trees that were manufactured into standard yard and structural lumber.

Yates, H. O. III

1966. *Rhyacionia* egg parasitism by *Trichogramma minutum* Riley. J. Econ. Entomol. 59: 967-969.

Factors are presented to explain the very high parasitism (64.5 percent) of *Rhyacionia* eggs by the parasite, *Trichogramma minutum.*

———

1966. Susceptibility of loblolly and slash pines to *Rhyacionia* spp. oviposition, injury, and damage. J. Econ. Entomol. 59: 1461-1464.

Rhyacionia oviposition and larval feeding occur on all four southern pines studied. Differential *Rhyacionia* larval survival following egglaying and initial shoot feeding was responsible for difference in host injury on loblolly and slash pine.

———

1967. Key to nearctic parasites of the genus *Rhyacionia*: with species annotations. USDA Forest Serv. Southeast. Forest Exp. Sta., 127 pp.

This reference paper reviews all the literature on parasites, indigenous and successfully introduced, of the whole genus *Rhyacionia* for the Nearctic Region and presents a key to these species. Over 100 verified parasites may be keyed to species. Another 26 species, considered erroneous, are omitted from the keys, however, reasons or authority for their deletion are discussed in the text. Effectiveness of keys are augmented by a series of 70 figures and line drawings. Each parasite species is listed separately and information summarized under the following headings: synonymy, size, range, hosts, and annotations. The annotations section includes notes on published information on each species.

One hundred and forty-one citations are included in the literature cited section and a complete index to scientific names is included to assist in locating published synonyms, misspellings, and erroneous combinations in the text.

(Limited distribution.)

———

1967. Larval migration of *Rhyacionia* spp. on pine shoots (Lepidoptera: Olethreutidae). J. Ga. Entomol. Soc. 2: 37-41.

Discusses the importance of larval migration and host phenology when applying chemicals for control of tip moth.

———

1967. Pupae of *Rhyacionia frustrana*, *R. rigidana*, and *R. subtropica* (Lepidoptera: Olethreutidae). Ann. Entomol. Soc. Amer. 60: 1096-1099.

Characters and key for the pupal separation of *Rhyacionia frustrana* (Comstock), *R. rigidana* (Fernald), and *R. subtropica* Miller are presented.

ates, H. O. III

1967. Radiographic detection of *Rhyacionia* larvae, pupae, parasites, and predators within pine shoots (Lepidoptera: Olethreutidae). J. Ga. Entomol Soc. 2: 81-85.

Diagnostic characters for the location and interpretation of *Rhyacionia* pupae, larvae, parasites, and predators are pictured and discussed.

———

1968. Minimizing losses in pine plantations due to insects. 7th Auburn Forest. Forum Proc. 1968: 3-9.

A general discussion of three of the most important plantation insects—pine reproduction weevils, tip moths, and bark beetles—with emphasis on cultural methods of minimizing losses due to these insects.

———

1968. Use of a radiopaque in radiography of forest insects. J. Ga. Entomol. Soc. 3: 137-140.

The use of radiopaque barium sulfate in the radiography of forest insects is discussed. This material, when injected into galleries, facilitates the mapping of insect galleries and, when painted on or fed to insects, provides an external or internal radiopaque marker that can be readily located on a radiograph.

———

1968. X-ray stalks old house borer. Pest Contr. 36(10): 52, 54, 56, 58-59.

An infestation of the old house borer in a residential home was radiographed with a portable X-ray machine. These radiographs enabled the builder to replace infested timbers.

The value of using radiography to study this pest control problem is pictorially demonstrated and discussed.

——— **and Lewis, W. G.**

1965. A new material to secure cage entrances. J. Econ. Entomol. 58: 787-788.

Outlines the use and advantages of Velcro to secure cage entrances. Positive closure is assured and is unaffected by warping, moisture, or dirt.

oung, C. E., Jr.

1964. Water management: key to wetland forest improvement in the southeast. (Abstr.) Assoc. South. Agr. Workers Proc. 1964: 61-62.

Presents information on the wetland forest universe, problems associated with managing wetland forests, preliminary research results on improving wetlands through drainage, and research activities of the Wetland Improvement Project in Charleston, South Carolina.

———

1966. Growth trends of loblolly pine on two drained wetlands. South. Lumberman 213(2656): 160-161.

Diameter and height growth of nine 10-year-old loblolly pines was measured for 2 years on a sandy ridge bay and heavy clay "Carolina" bay near Charleston, South Carolina. These measurements were compared to precipitation amounts and water table levels for the same period. This case study showed that growth was better during a wet year, when water table levels were higher, than during a dry year, when lower water levels prevailed. Moreover, growth was also considerably better on the heavy soil than the light soil.

McSwain, M. P.

1970. Publications of the Southeastern Forest Experiment Station, 1964-1968. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-71, 123 pp.

An annotated list of 695 reports authored by members of the Station research staff and cooperators from 1964 through 1968.

McSwain, M. P.

1970. Publications of the Southeastern Forest Experiment Station, 1964-1968. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-71, 123 pp.

An annotated list of 695 reports authored by members of the Station research staff and cooperators from 1964 through 1968.

McSwain, M. P.

1970. Publications of the Southeastern Forest Experiment Station, 1964-1968. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-71, 123 pp.

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The Forest Service, U. S. Department of Agriculture, is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

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Soil Compaction and Loosening Treatments Affect Loblolly Pine Growth in Pots

Glyndon E. Hatchell

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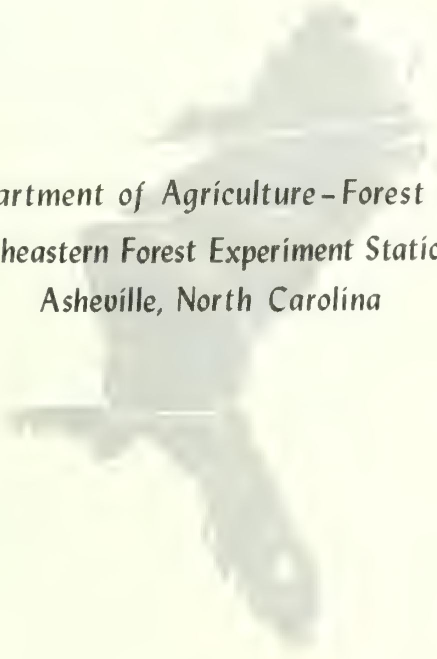

U.S. Department of Agriculture-Forest Service
Southeastern Forest Experiment Station
Asheville, North Carolina

Soil Compaction and Loosening Treatments Affect Loblolly Pine Growth in Pots

by

Glyndon E. Hatchell, Associate Soil Scientist
Charleston, South Carolina

Soil disturbance in logging is a factor of growing importance in the Southeast because of the increased use of heavy logging equipment. Recent observations indicated that poor establishment and reduced growth of loblolly pine seedlings were prevalent on severely disturbed, medium- to fine-textured soils of the lower Atlantic Coastal Plain, but the actual soil factors causing poor growth were not evident.

Foil and Ralston (1967) found that root weight of loblolly pine seedlings grown in a greenhouse was negatively correlated with bulk density over a range in density from 0.8 to 1.4 $g./cm.^3$. They concluded, however, that no single factor was entirely responsible for retarding seedling growth at high soil densities. With crop plants, root growth is restricted at high soil density by low oxygen supply and mechanical resistance, and possibly by the interaction of these factors (Horton 1962; Rosenberg 1964). Possible detrimental effects from high carbon dioxide concentrations or other toxic gases which accumulate during poor aeration cannot be ruled out (Chang and Loomis 1945).

The study reported here was designed to assess the responses of loblolly pine seedlings grown in pots containing undisturbed cores of compacted and noncompacted soils. Loosening treatments were applied to the cores to test possible restorative measures.

METHODS

Undisturbed soil cores, 4 inches in diameter and 6 inches in depth, were taken from surface horizons of normal and compacted soils representing major textural and drainage classes on the Santee Experimental

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Work done in cooperation with Duke University. The assistance and guidance of C. W. Ralston, Dean, School of Forestry, is gratefully acknowledged.

Forest in Berkeley County, South Carolina. Each of the five soil types selected were represented at two locations. Cores of compacted soil were taken from ruts formed the previous year by nine trips with a tractor-drawn trailer approximating normal pulpwood loads (Foil 1965). Three soil cores were taken from compacted soil at each of the 10 locations, and three cores were collected from normal, noncompacted soil adjacent to each compacted plot. Cores from each plot were randomly assigned the following treatments: (1) loosening the entire 6-inch core; (2) loosening surface soil to a 3-inch depth; and (3) no loosening. To loosen the soil, the core was removed from the pot and broken into particles $\frac{1}{4}$ inch in diameter or smaller and then loosely packed into the pot so that the height of the soil column was increased 1 inch, an increase in volume of approximately 17 percent. Pots and soil were fumigated with methyl bromide for insect and disease control.

Loblolly pine seed with 99 percent soundness were stratified under moist and cool conditions for 30 days. Twenty-five seeds per pot were placed on the soil surface on July 23, and germination peaked within 10 days. Frequent observations were made as seedlings were germinating. Seedling establishment was assessed 30 days after sowing; at this stage, each pot was thinned to five seedlings, all of which survived to the end of the experiment. Pots were kept in a shadehouse until midseason, then in a greenhouse until growth ceased in late fall. Soil moisture was maintained in the upper range of plant availability. Seedlings were harvested in December of the first year when ovendry weight of shoots and roots was determined separately.

The following soil physical properties and aeration conditions were determined for each pot: oxygen diffusion rate; bulk density; and detention and retention storage at 60-cm. soil moisture tension to estimate capillary and noncapillary porosity. The platinum microelectrode technique (Stolzy and Letey 1964) was used to measure oxygen diffusion rate at 60-cm. tension at the beginning of the study--the approximate moisture content immediately after watering, at which time one would expect the least amount of oxygen--and it was measured again at approximately the same moisture content when seedlings were 1 month old. Measurements were made at $\frac{1}{2}$-inch, $1\frac{1}{2}$-inch, and $4\frac{1}{2}$-inch depths in soil to estimate average oxygen diffusion rate.

RESULTS AND DISCUSSION

Seedling Establishment

Establishment was lower on compacted soils than on noncompacted soils, but loosening the compacted surface greatly increased establishment on four of the five soil textural classes (table 1). On clay loam, neither compaction nor loosening treatments had much effect on seedling establishment, apparently because compacted clay loam had a relatively low bulk density (1.12 g./cm.^{3} for samples of compacted soils and 1.04 g./cm.^{3} for cores of noncompacted soils, table 1) compared to the other four soils (averaging 1.46 and 1.26 g./cm.^{3} for compacted and noncompacted cores, respectively). An analysis of variance which excluded the clay loam samples indicated that compaction resulted in a highly significant reduction in seedling establishment and that loosening and the interaction of compaction and loosening had significant effects on establishment. Loosening substantially improved establishment on compacted soils, but not on noncompacted soils. There were no significant differences in establishment on loamy sand, loam, silt loam, and sandy clay loam soils.

Table 1.--Loblolly pine seedlings established and bulk density of soil cores by soil types, compaction, and loosening treatments

Surface soil texture	Compacted soil				Noncompacted soil			
	Loosening depth (inches)				Loosening depth (inches)			
	0	3	6	Mean	0	3	6	Mean
	Establishment percent[1]							
Loamy sand	78	92	94	88	92	94	94	93
Loam	64	92	96	84	98	100	92	97
Silt loam	74	86	92	84	94	98	100	97
Sandy clay loam	76	90	82	83	100	98	92	97
Clay loam	84	86	86	85	86	88	86	87
Mean	75	89	90	85	94	96	93	94
	Bulk density (g./cm.^{3})							
Loamy sand	1.46	1.27	1.23	1.32	1.26	1.14	1.10	1.17
Loam	1.47	1.20	1.19	1.29	1.30	1.10	1.15	1.18
Silt loam	1.62	1.35	1.30	1.42	1.34	1.18	1.11	1.21
Sandy clay loam	1.28	1.08	1.06	1.14	1.14	1.12	.97	1.08
Clay loam	1.12	.87	.93	.97	1.04	.92	.92	.96
Mean	1.39	1.15	1.14	1.23	1.22	1.09	1.05	1.12

[1] Based upon the number of sound seeds sown.

Losses during germination were primarily due to restricted penetration of the radicle. Such losses were observed in significantly greater quantities on compacted soils that had no loosening than on compacted soils which were loosened or noncompacted soils which were not loosened (fig. 1). Losses from failure of the radicles to penetrate the soil surface (expressed as a percentage of sound seed and excluding clay loam) were 12.5, 1.0, and 0.5 percent on compacted soil loosened to 0-, 3-, and 6-inch depths; and respective values for noncompacted soils were 1.0, 0.0, and 1.5 percent. These results agree with those of Pomeroy (1949) who observed reduced germination rate and increased mortalty rate of loblolly pine seedlings on silt loam and clay loam soils that had been compacted or puddled by logging equipment. He concluded that high mortality occurred when radicles failed to penetrate compacted surfaces.

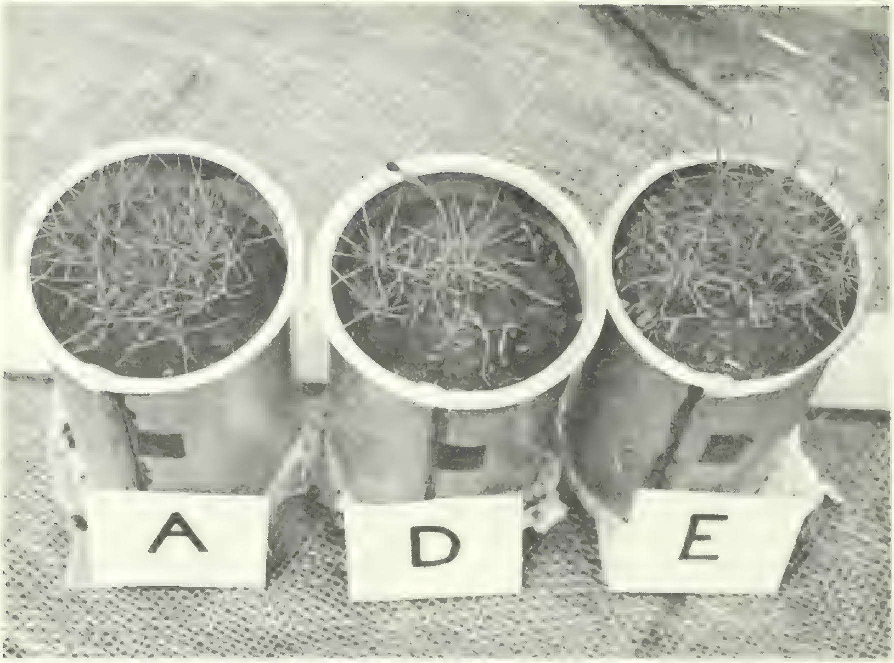

Figure 1.--One-month-old loblolly pine seedlings on (A) normal soil without surface loosening; (D) compacted soil without surface loosening; and (E) compacted soil loosened to 3-inch depth. Radicles of many seedlings failed to penetrate compacted surface (D), but loosening the soil surface greatly increased seedling establishment.

Seedling Growth

Response to soil compaction.--Analyses of seedling responses on compacted and noncompacted soils revealed a highly significant reduction in dry shoot weight on compacted soils, and a highly significant soils x compaction interaction. A set of orthogonal comparisons that tested this interaction indicated: (1) that compaction reduced dry shoot weight to a lesser extent on loamy sand than on the four soils with a finer texture; and (2) that the compaction treatment reduced shoot growth significantly more on sandy clay loam soil than it did on clay loam soil. Compaction also resulted in a highly significant reduction in dry root weight, but shoot/root ratio was not significantly affected by compaction, soil type, loosening treatments, or their interactions. One orthogonal comparison of shoot growth that tested the soils-loosening interaction was found statistically significant, although the outcome could not be clearly interpreted. This was a comparison of the quadratic effect of loosening on loam and silt loam soils versus sandy clay loam and clay loam soils. On loam and silt loam soils, the 3-inch loosening depth provided greater shoot growth than loosening to the 0- and 6-inch depths, but the quadratic effect of loosening (3-inch depth versus 0- and 6-inch depths) was not pronounced on sandy clay loam and clay loam soils.

It is noteworthy that the greatest growth retardation on compacted soil as compared to noncompacted soil (table 2) was observed on silt loam soil (the response on silt loam versus the overall response on the other four soils was not included in the set of orthogonal comparisons selected before the experiment was conducted). This finding is attributed to a higher bulk density of silt loam soil compared to the other four soils (table 1).

Table 2.--Dry weights of shoots and roots of 1-year-old loblolly pine seedlings as related to soil texture, compaction, and loosening treatments

Surface soil texture	Compacted soil				Noncompacted soil			
	Loosening depth (inches)				Loosening depth (inches)			
	0	3	6	Mean	0	3	6	Mean
				Shoot weight (mg.)				
Loamy sand	156	312	306	258	270	224	272	255
Loam	122	170	150	147	183	514	135	277
Silt loam	131	158	148	146	297	476	316	363
Sandy clay loam	283	155	184	207	638	370	341	450
Clay loam	230	262	246	246	332	248	239	273
Mean	184	211	207	201	344	366	261	324
				Root weight (mg.)				
Loamy sand	50	126	110	95	111	66	105	94
Loam	36	60	56	51	60	164	52	92
Silt loam	52	53	52	52	104	126	102	111
Sandy clay loam	108	66	58	77	152	126	106	128
Clay loam	83	88	93	88	100	81	90	90
Mean	66	79	74	73	105	113	91	103

Mean root and shoot growth on noncompacted soils with no loosening was less than that attained from loosening to the 3-inch depth, but greater than that attained from loosening the entire 6-inch core (table 2). Loosening the entire core under high moisture conditions (60-cm. tension) may have caused adverse structural changes, particularly for samples which included a portion of the finer textured B horizon. Responses from loosening cores of normal soils were not closely related to textural classes; loosening resulted in an increase in ovendry seedling weight on loam, silt loam, and clay loam soils, but it decreased seedling weight on loamy sand and sandy clay loam soils. Foil and Ralston (1967) observed that loosening 5-inch core samples from their normal structure reduced loblolly pine seedling growth on loamy sand and loam soils, but stimulated growth on clay soils. In another pot study, Clark (1964) found a much higher growth rate of yellow-poplar seedlings in undisturbed forest soils of silt-loam texture than in the same soils sieved through a large mesh screen. He concluded that destroying the macrostructure of the soil created conditions of poor drainage and aeration and drastically retarded yellow-poplar seedling growth. The contrasting results in these experiments may have originated from different moisture regimes and subsequent changes in the soil environment.

Loosening compacted soils did not produce a significant increase in growth of shoots and roots. Mean dry shoot weights for compacted soils loosened to 0-, 3-, and 6-inch depths were, respectively, 184, 211, and 207 mg., and respective root weights were 66, 79, and 74 mg.; these weights are considerably less than those on noncompacted soils with no loosening--344 mg. for shoots and 105 mg. for roots (table 2). Mean bulk densities of compacted samples loosened to 0-, 3-, and 6-inch depths were, respectively, 1.39, 1.15, and 1.14 g./cm.^{3}, compared to a mean density of 1.22 g./cm.^{3} for noncompacted soils with no loosening (table 1). Possibly some of the growth differential on compacted and noncompacted soil cores was caused by vehicular traffic that displaced a portion of the naturally shallow A horizons and the inclusion of a greater proportion of the B horizon in samples of compacted soils, thus lowering the fertility level and increasing the water retention of compacted soils compared to noncompacted soils. Another possibility is that large variability in the properties of soil cores collected from the same plot (within-plot variability), coupled with a limited number of replications, could have resulted in an insensitive test of loosening of compacted soils as a restorative measure.

Many years may be required to obtain the full benefits from loosening compacted soils. Vomocil and Flocker (1965) observed that soil compaction can cause a degradation of soil structure of such complexity that even crushing and sieving may not remove the evidence of compaction. Loosening compacted soils may effectively provide a favorable environment for gradual improvement of soil tilth by natural forces, such as wetting and drying, freezing and thawing, and soil fauna and flora. Nichols, Cooper, and Reaves (1955) pointed out that the main objective of using machinery to loosen compacted soil is not to pulverize the soil in an attempt to return it immediately to a state of good tilth, but to stimulate the action of natural forces.

The continuing progress made by intensive agronomic research on soil compaction problems (Rosenberg 1964) indicates that a concentrated research effort will be required to provide a full understanding of the consequences of disturbing forest soils. Long-term studies that test ameliorative treatments should provide the necessary information for prudent practices to alleviate the detrimental conditions in severely disturbed forest soils.

Relations of responses to soil variables.--The relations of seedling responses to bulk density, the reciprocal of bulk density, noncapillary porosity, oxygen diffusion rate, and four variables expressing bulk density–aeration interactions were tested by correlation analysis (table 3). Shoot/root ratio was significantly correlated with six of the eight independent variables tested; bulk density and its reciprocal were nonsignificant variables. The ratio of shoots to roots decreased with increasing noncapillary porosity or "normal air space," indicating that the proportion of roots increased as air space increased. The shoot/root ratio decreased with increasing oxygen diffusion rate, which suggests that a low oxygen supply caused poorer root growth in comparison to shoot growth. Dry root weight was significantly correlated with only one variable, $\frac{1}{\text{bulk density}}$ x oxygen diffusion rate. Root weight was lowest at low oxygen diffusion rate, and with a constant oxygen diffusion rate there was a curvilinear decline in dry root weight with increasing bulk density. However, root weight and shoot/root ratio were not closely related to the soil variables which were tested, because significant variables accounted for only 6 to 10 percent of the variation in yields (table 3). None of the soil variables were related to dry shoot weight, which indicated that under the favorable moisture conditions maintained in this study, the poorly developed root systems were able to support a relatively good growth of shoots.

In assessing the effects of soil compaction on seedling growth, three soil factors were analyzed--bulk density, noncapillary porosity, and oxygen diffusion rate. These soil factors were interrelated and are direct or indirect expressions of soil aeration. Compaction alters a number of

Table 3.--Sample linear correlation coefficients between seedling responses and soil variables

Independent variable	Dependent variable		
	Dry shoot weight	Dry root weight	Shoot/root ratio
	- - - - - Correlation coefficient (r) - - - - -		
Noncapillary porosity	+.084	+.237	-.318* (r^2 = .101)
Bulk density	-.170	-.203	+.076
(Bulk density) x (Noncapillary porosity)	+.056	+.207	-.310* (r^2 = .096)
$(\frac{1}{\text{Bulk density}})$	+.110	+.148	-.095
$(\frac{1}{\text{Bulk density}})$ x (Noncapillary porosity)	+.088	+.230	-.302* (r^2 = .091)
Oxygen diffusion rate	+.051	+.208	-.306* (r^2 = .094)
(Bulk density) x (Oxygen diffusion rate)	-.011	+.129	-.283* (r^2 = .080)
$(\frac{1}{\text{Bulk density}})$ x (Oxygen diffusion rate)	+.092	+.254* (r^2 = .065)	-.311* (r^2 = .097)

[*] Significant at the 5-percent level with 58 degrees of freedom (Snedecor 1956).

other soil properties that may affect plant growth, including strength, structure, shrinkage properties, and permeability. Strength is an important factor because the high strength associated with high densities causes greater mechanical resistance to root growth (Phillips and Kirkham 1962).

Dry root weight and shoot/root ratio of loblolly pine seedlings in this experiment were related to oxygen diffusion rate per unit bulk density, which suggests an interaction between oxygen diffusion rate and soil strength because soil strength increases with increasing bulk density. Reduced root growth on soils with high bulk densities and low oxygen diffusion rates may have been caused by the combined effects of low oxygen supply to roots and mechanical resistance at high soil strength. Where low oxygen diffusion rates occurred at low bulk densities, oxygen may have been the limiting factor.

SUMMARY AND CONCLUSIONS

Establishment and growth of loblolly pine seedlings on compacted cores were substantially less than on cores of normal soil. Loosening compacted cores resulted in an establishment percentage which was almost as high as the percentage on cores of normal soil, but loosening compacted cores did not significantly improve growth.

The effectiveness of loosening compacted soils as a restorative treatment should be appraised in long-term field tests. On portions of logging chances where soil compaction effects are severe, such as decking areas and primary skid trails, disking or other cultivation techniques should be tested as remedial treatments. Such treatments should immediately improve aeration conditions by breaking up the compact layer and providing better surface and internal drainage. These alterations should also provide a more favorable environment for the gradual improvement of tilth by natural forces. If effective, the cost/benefit ratios of these treatments should be quite favorable because establishment and growth of loblolly pine is hindered appreciably on severely compacted soils and their restoration by natural processes is exceedingly slow.

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DA Forest Service Research Paper SE-73 December 1970

Optimum Depth and Season for Direct Seeding Slash Pine in South Florida

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Optimum Depth and Season for Direct Seeding Slash Pine in South Florida

by

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The interior of southern Florida, with millions of acres of cutover pine land, offers a tremendous opportunity for large-scale direct seeding of pines. Among the factors to consider in developing reliable seeding methods are species, season, and depth of seeding.

This paper is based on two concurrent studies--one designed to determine the optimum depth and the other to establish the best season for seeding South Florida slash pine (Pinus elliottii var. densa Little & Dorman) and typical slash pine (Pinus elliottii var. elliottii) in south Florida. Another objective of each study was to compare the success in germination and early survival of these varieties.

Nursery-grown seedlings of both varieties are planted in south Florida. Typical slash pine consistently exhibits better survival and early growth, while South Florida slash pine is favored because of greater fire resistance, greater resistance to insects and some diseases, and relatively less growth loss following cattle damage (Bethune 1966). It has been hypothesized that the relatively poor survival and early growth of planted South Florida slash pine are the result of transplanting difficulties, and if so, direct seeding might prove to be the best means of regenerating this native variety.

DEPTH-OF-SEEDING STUDY

Show (1917) recognized early that both germination and the morphological grade of conifer seedlings are influenced by seeding depth. However, comprehensive recommendations are not possible for conifers in general. The optimum sowing depth for given soil and climatic conditions varies by species (Show 1917; Shipman 1963). Similarly, the optimum sowing depth for any given species varies with soil and climatic conditions (Hodgkins 1966; Malahovec 1963; Mann and Derr 1961, 1964; Shipman 1963). No work on depth of sowing has been done under south Florida conditions.

Procedure

Arasan-Endrin* treated seed of the two varieties were sown at six depths in November and April of 1962-63 and 1963-64. The study was on a Leon fine sand at the Florida Forest Service Herren Forest Nursery near Punta Gorda, Florida. Freshly prepared, unfertilized nursery beds were sown at depths ranging from the surface to 1.25 inches, in 0.25-inch increments. Each plot (or statistical observation) consisted of 144 seed spots within a 2- by 2-foot square; only the inner 100 spots were counted. Spacing was controlled with a 2- by 2-foot hardboard template with holes bored on a systematic grid. The desired depth was achieved by punching a metal bolt with a movable collar through each template hole into the soil below. A seed was then dropped into each hole and the holes were refilled to surface level. A randomized block design was employed, with four replications of 24 factorial treatments (6 depths x 2 varieties x 2 months) within each seeding year.

Germination

As used here, germination of a surface-sown seed was achieved when the radicle penetrated the soil surface and the seedcoat lifted clear of the ground. Germination of a buried seed was achieved upon the emergence of any portion of the plant from the soil.

During both years the November sowings succeeded and the April sowings failed. Extended dry periods were responsible for both the April failures and precluded further statistical treatment or discussion of that month's sowings.

Germination of the November sowings varied significantly[1] by depth of sowing, variety of slash pine, year of sowing, and the two-way interactions of these factors. During the 2 years of the study, 64 percent of the November-sown typical slash pine seed and 58 percent of the South Florida slash seed germinated. South Florida slash varied from a low of 46 percent in 1962 to 71 percent in 1963, while typical slash germination was consistent at 64 percent for the 2 years.

A significant interaction between depth and variety resulted from an apparent greater sensitivity of typical slash pine than South Florida slash to depth of sowing (fig. 1). The range in total germination was 30 percent for typical slash and 15 percent for South Florida slash pine. The optimum depth for typical slash was between 0.25 to 0.50 inch. This agrees with Jones' (1963) findings in a similar study in the Middle Coastal Plain of Georgia. The 0.25- to 0.75-inch range appears best for South Florida slash, although the relatively slight differences in germination at varying depths may be due to chance.

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*As with any repellent or pesticide, this compound should be handled with caution to protect personnel and environment. After recent re-evaluation, Forest Service recommendation for use of Endrin on coniferous tree seed is set at 0.5 percent active Endrin.

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[1] Reference to significance in this paper relates to not less than the 95-percent level of confidence.

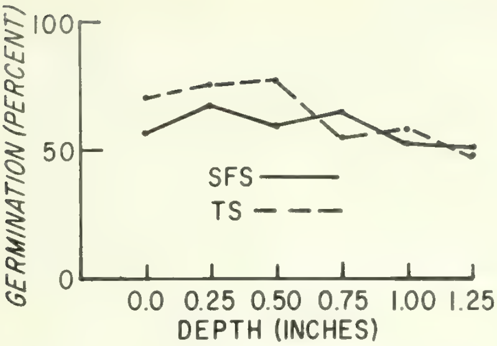

Figure 1.--Percentage germination of November-sown seed of typical slash (TS) and South Florida slash (SFS) for 1962 and 1963 combined.

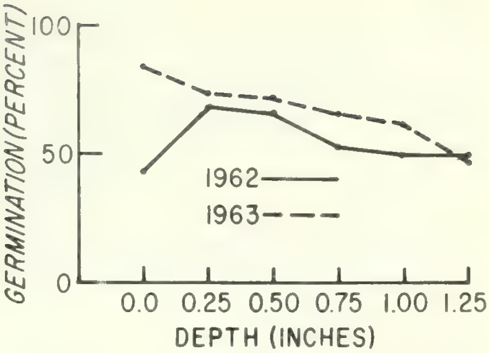

Figure 2.--Percentage germination of November-sown seed on the surface was low for both varieties in 1962 because a short, dry period followed seeding.

Moisture was apparently adequate at the time of both November sowings, but a short dry period after the 1962 sowing probably accounts for the difference in germination at the surface between the 2 years (fig. 2).

Mortality

Mortality of germinant seedlings by midsummer following the respective sowings was 12 percent the first year and 7 percent the second year. Mortality was not affected by planting depth, year, nor variety.

SEASON-OF-SOWING STUDY

Mann and Derr (1964) recognized season as the most difficult factor to consider in formulating general guidelines for direct seeding of slash pine. Climographs for Fort Myers, Florida, Albany, Georgia, and Cheneyville, Louisiana, exemplify climatic patterns within the range of slash pine (fig. 3). Compared to the other locations, Fort Myers experiences a drastically greater range of mean monthly rainfall. Reliable seeding guidelines are available for the Cheneyville area (Mann and Derr 1964), and the same guidelines possibly may be used in the Albany area with little modification. The need for careful testing in the Fort Myers area is obvious.

Procedure

This study was conducted at the Corkscrew Experimental Forest in Collier County and the Caloosa Experimental Range in Charlotte County.[2] Soils at both plot areas are Leon fine sand. Arasan-Endrin treated seed of the two slash pine varieties were sown monthly at midmonth from October through May for three seasons (1962-63 to 1964-65). The experimental design consisted of two randomized blocks at each of the two locations. All plots were disked and hand-raked each summer prior to sowing to provide a debris-free mineral seedbed. The sowing consisted of pressing the seed by hand into the soil and barely covering them. Each plot included 25 systematically spaced seed spots at which four seed each were sown. Seed spots were protected from rodents and large insects by cones of $\frac{1}{4}$-inch hardware cloth.

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[2] The Corkscrew Forest is owned by Alico Land Development Company and the Caloosa Range is owned by Babcock Florida Company. These lands are leased for research purposes to the Southeastern Forest Experiment Station in cooperation with the Florida Division of Forestry.

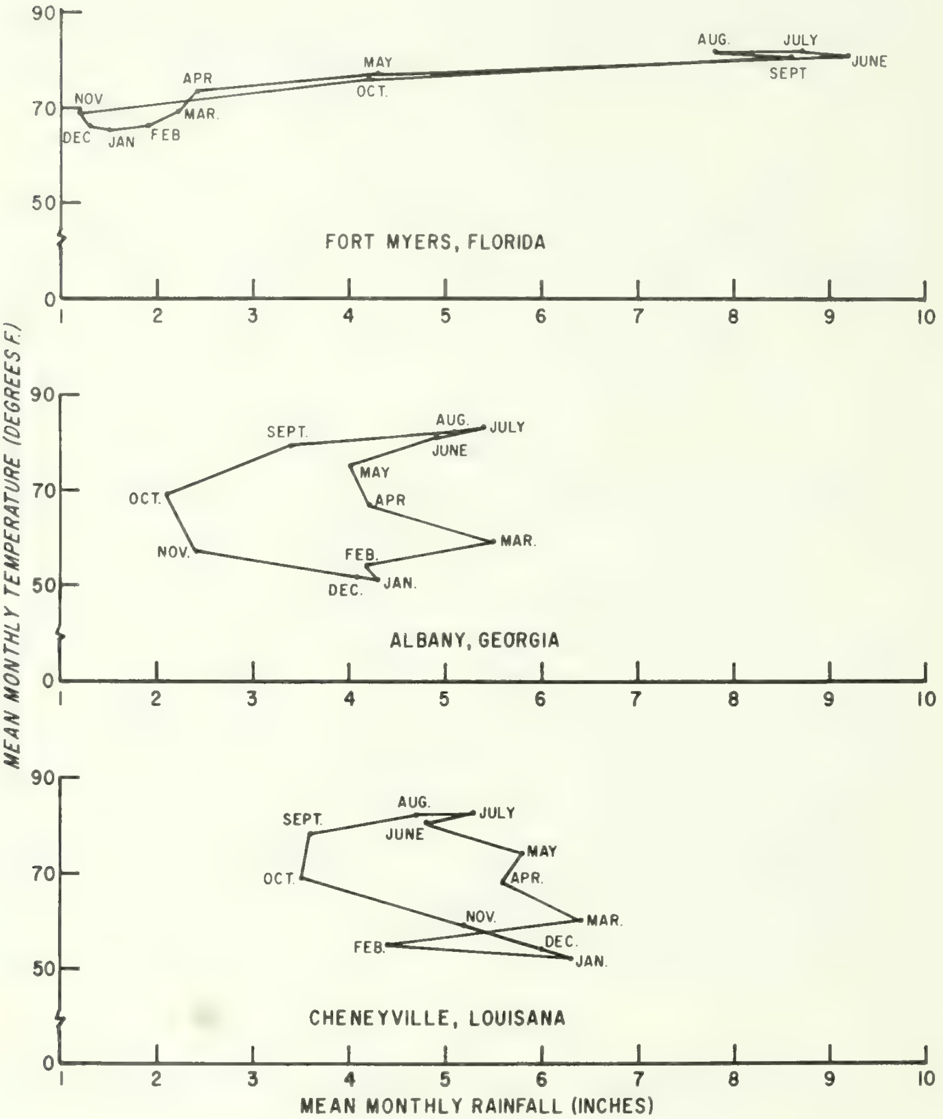

Figure 3.--Climographs for Fort Myers, Florida, Albany, Georgia, and Cheneyville, Louisiana. (Data from: Hocker, Harold W., Jr. 1955. Climatological summaries for selected stations in and near the southern pine region, 1921-1950. USDA Forest Serv. Southeast. Forest Exp. Sta. Pap. 56, 11 pp.)

Seedling Establishment

The percentage of seed that results in seedlings is a measure of successful seedling establishment. This relationship is called "tree percentage" (Baker 1950). It is the actual result of treatment, since both germination and mortality of germinant seedlings are included in its calculation.

Tree percentage during the summer following each sowing season varied significantly by month and year, but not by variety. Figure 4 presents the mean and range in tree percentage by month for the 3 years of the study. Average tree percentage for the period October through February was favorable, contrasted against that of March, April, and May. Of the favorable months, October had the narrowest range and the highest minimum tree percentage. November exhibited a high mean value, with a minimum value higher than the mean of any poor month. The December mean was satisfactory, but the minimum approximated the means for March, April, and May. While the January and February means were reasonably high, the minimum values for those months were unacceptably low. This pattern suggests that fall seeding should be favored over winter and spring seeding, and that early fall is probably better than late fall. These conclusions contrast with findings of Varnell and Bennett (1966), who concluded that the most favorable time "... in the flatwoods of the Atlantic Coastal Plain lies between the first of February and the middle of March."

Total germination, mortality, and the resulting tree percentage were similar for the two varieties over the 3-year period of the study (fig. 5).

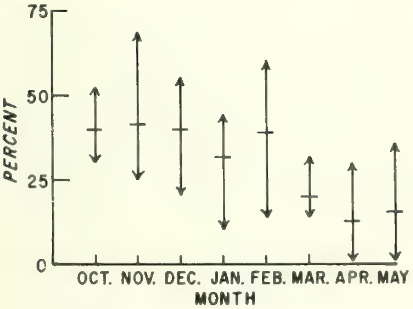

Figure 4.--Means and ranges of tree percentage for both varieties during the 3 years of the Season-of-Sowing Study.

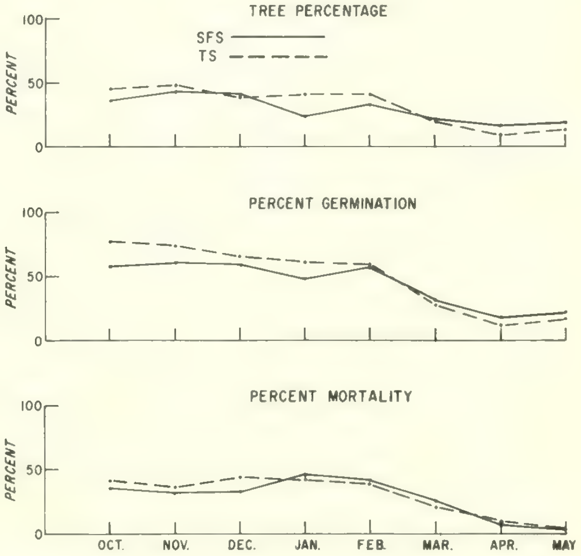

Figure 5.--Tree percentage, percentage germination, and percentage mortality were similar for the two varieties during the 3 years of the study.

DISCUSSION AND CONCLUSIONS

In the Depth-of-Seeding Study the trend was toward lower germination with increasing depth. It is speculated that, given limited moisture, the highest germination will occur at the shallowest depth offering adequate moisture.

In the Season-of-Sowing Study, satisfactory germination and survival occurred consistently only during October, November, and December. Rainfall is so high from June through September (fig. 3) that flooding would probably be a limiting factor, and therefore these months were not studied.

Though not specifically tested, a strong interaction between month and depth of seeding may be expected. Shallow- or surface-sown seed should germinate more readily than deeper-sown seed during the fall because the rainfall pattern suggests ample surface moisture then. Conversely, higher percentage of deep-sown than shallow-sown seed should germinate during the winter and spring because surface moisture is likely to be limiting during that period. The Depth-of-Seeding Study was not replicated over enough months and years to confirm or contradict this hypothesis.

Indications are that fall seeding will produce the best overall results and that broadcast seeding should be confined to this period. If row-seeding is employed, it should be accomplished in the fall if possible, with only a light soil covering. If fall seeding is not possible, row-seeding should be done at a depth of approximately $\frac{1}{2}$ inch.

The similar response of the two varieties suggests that, although they have been exposed to different climatic patterns (at least in recent geologic history), they still possess the same general requirements for successful germination and establishment. The comparable performance of these varieties lends support to the hypothesis that relatively poor survival of planted South Florida slash seedlings is the result of transplanting difficulties. These results, coupled with the knowledge that South Florida slash pine is more resistant to fire, insects, and some diseases in south Florida, demonstrate the feasibility and desirability of perfecting direct-seeding techniques for this variety in its native range. This is analogous to the situation with longleaf pine (Pinus palustris Mill.) which, although difficult to transplant successfully, can now be seeded economically and reliably on the sites to which it is adapted (Mann 1968).

Results of these studies offer reasonably reliable guides for the factors tested, but other factors, such as seedling predation may limit the success of stand establishment by direct seeding. The importance of these other factors must be determined before large-scale direct seeding can be recommended for south Florida.

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The paper discusses two studies--one designed to determine the optimum depth and the other to determine the best season for seeding slash pine in south Florida. All seeding should be accomplished in the fall, if possible, and broadcast seeding should be confined to the fall. Fall row-seeding should employ only a light soil covering; if seeding is attempted in spring, the seed should be planted to a depth of approximately $\frac{1}{2}$ inch.

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SDA Forest Service Research Paper SE-74 January 1971

Equilibrium Moisture Content of Common Fine Fuels Found in Southeastern Forests

by

W. H. Blackmarr

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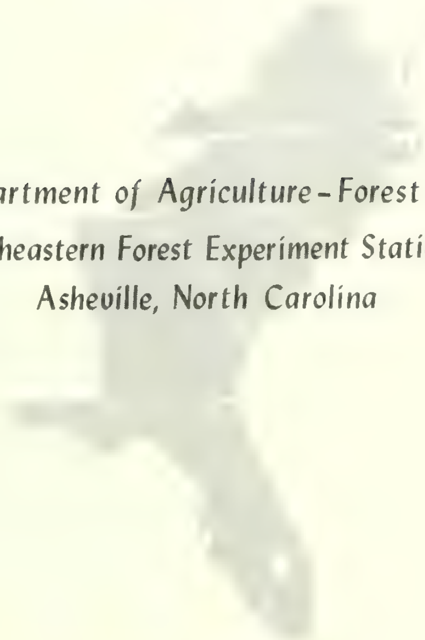

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Equilibrium Moisture Content of Common Fine Fuels Found in Southeastern Forests

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INTRODUCTION

Moisture content is one of the more important fuel conditions affecting forest fire behavor, and it can be estimated from samples of fuel collected from the forest stand. For fire danger prediction or the prediction of favorable conditions for prescribed burning, however, this is usually impractical because of the time and work that it requires.

Although the prediction of fuel moisture through its correlation with certain weather factors is convenient, it may be inaccurate for two reasons. First, fuel particles and fuel complexes vary so widely in their response to the influence of weather that the relationship of fuel moisture to weather is not completely understood. Second, there is a lack of reliable instruments which can intensively sample the important meteorological parameters and then integrate these measurements into accurate estimates of fuel moisture content.

Most of the fine fuel on the forest floor consists of cured leaves and small woody stems from a variety of plant species (except in plantations). These materials vary in the way their moisture content responds to fluctuating relative humidity. Their EMC's[1] differ as a result of inherent differences in the chemical and physical nature of each kind of fuel. Their EMC's also differ according to whether they are approached from a previously dry or wet condition.

The moisture content of forest fuels does not often reach equilibrium because atmospheric humidity is seldom constant. The rate at which fine fuel particles gain or lose moisture depends on their degree of exposure to agents such as wind, solar radiation, and precipitation which influence the exchange of moisture between the fuel particle and atmosphere. The complex arrangement of fine fuel particles on the forest floor can produce wide variations in the moisture content throughout the fuel layer because of varying degrees of exposure of individual fuel particles to wetting and drying forces.

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[1] The equilibrium moisture content (EMC) of a fuel is that moisture content which the fuel will attain after prolonged exposure to an atmosphere of constant relative humidity and temperature.

Equilibrium moisture content data have been reported for many kinds of cellulosic materials. Most of these are for wood or wood products[2] and textile fibers.[3] The EMC's of most cellulosic materials vary from 0 to about 30 percent of their dry weight. This is true for relative humidities from 0 to about 99.5 percent. Between 99.5 and 100 percent relative humidity, EMC's may reach as high as 150 percent.[4] Few EMC data have been reported for materials that make up the fine fuel complexes of the forest floor. However, King and Linton[5] have reported EMC data for eight different natural fuels found in Australian forests. These include pine needles, eucalyptus leaves and bark, brachen fern, and grass.

METHODS

Dead leaves from the following plant species:

Loblolly pine (*Pinus taeda* L.)

Slash pine (*Pinus elliottii* Engelm.)

Longleaf pine (*Pinus palustris* Mill.)

Southern red oak (*Quercus falcata* Michx.)

Post oak (*Quercus stellata* Wangenh.)

Mockernut hickory (*Carya tomentosa* Nutt.)

Wiregrass (*Aristida stricta* Michx.)

Broomsedge (*Bromus secalinus* L.)

and sawdust from a freshly cut loblolly pine log were subjected to stepwise changes in relative humidity at a constant temperature of 80° ± 1.5° F. The equilibrium moisture content of the fuel materials was determined at each relative humidity.

Bulk samples of each fuel material were first dry-homogenized and dried to approximately 1 percent moisture content in an oven at 130° F. Homogenization should not affect the EMC since the amount of surface available for adsorption of water molecules inside the fuel particles is negligibly affected by such treatment. The bulk samples were then placed in a controlled-atmosphere chamber (fig. 1) and subjected to stepwise increases in relative humidity ranging from 3 to 92 percent. The bulk samples were then soaked in water for 48 hours and subjected to stepwise decreases in relative humidity from 92 to 1.5 percent.

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[2] Stamm, Alfred J. Wood and cellulose science. 549 pp. New York: Ronald Press Co. 1964.

[3] Urquart, A. R. Sorption isotherms, pp. 14-32, ch. III. *In* J. W. S. Hearle and R. H. Peters, Moisture in textiles. New York: Textile Book Publ., Inc. 1960.

[4] Stamm, *loc. cit.*

[5] King, A. R., and Linton, M. Report on moisture variation in forest fuels: equilibrium moisture content. Commonwealth Sci. & Ind. Res. Organ. Australia, Melbourne, 9 pp. 1963.

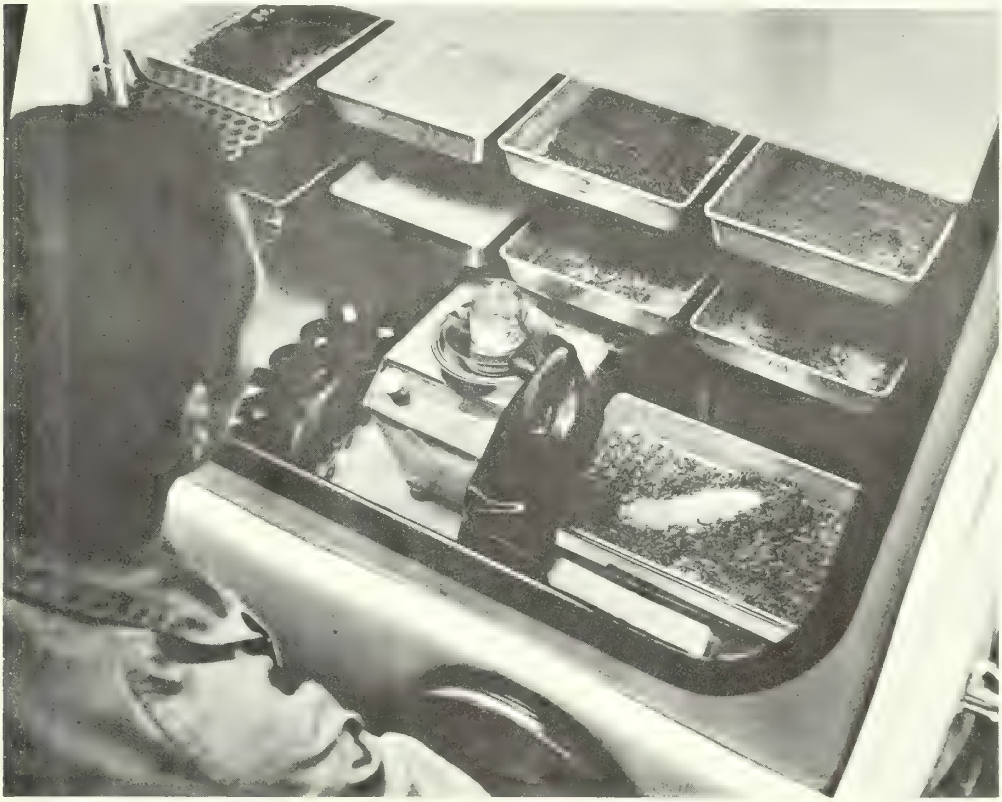

Figure 1.--Bulk samples of fuel material were conditioned at constant relative humidity and temperature in this controlled-atmosphere glove box. Subsamples were collected to determine the moisture content at each level of relative humidity.

We maintained constant relative humidity at each step by recirculating the air in the chamber through a reagent bottle (fig. 2) containing a saturated salt solution. The salts used were selected from the list in the Handbook of Chemistry.[6] We measured the relative humidity in the chamber with wet and dry bulb precision thermometers which were mounted in the return air duct. Temperature in the glove box was held constant by a small heat element mounted in the incoming air duct. By keeping the temperature in the laboratory slightly below 80° F., the heat element was able to maintain the glove box temperature at 80° ± 1.5° F.

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[6] Lange, Norbert A. Solutions for maintaining constant humidity, p. 1420. In Handbook of chemistry. Ed. 10. New York: McGraw-Hill Book Co., Inc. 1961.

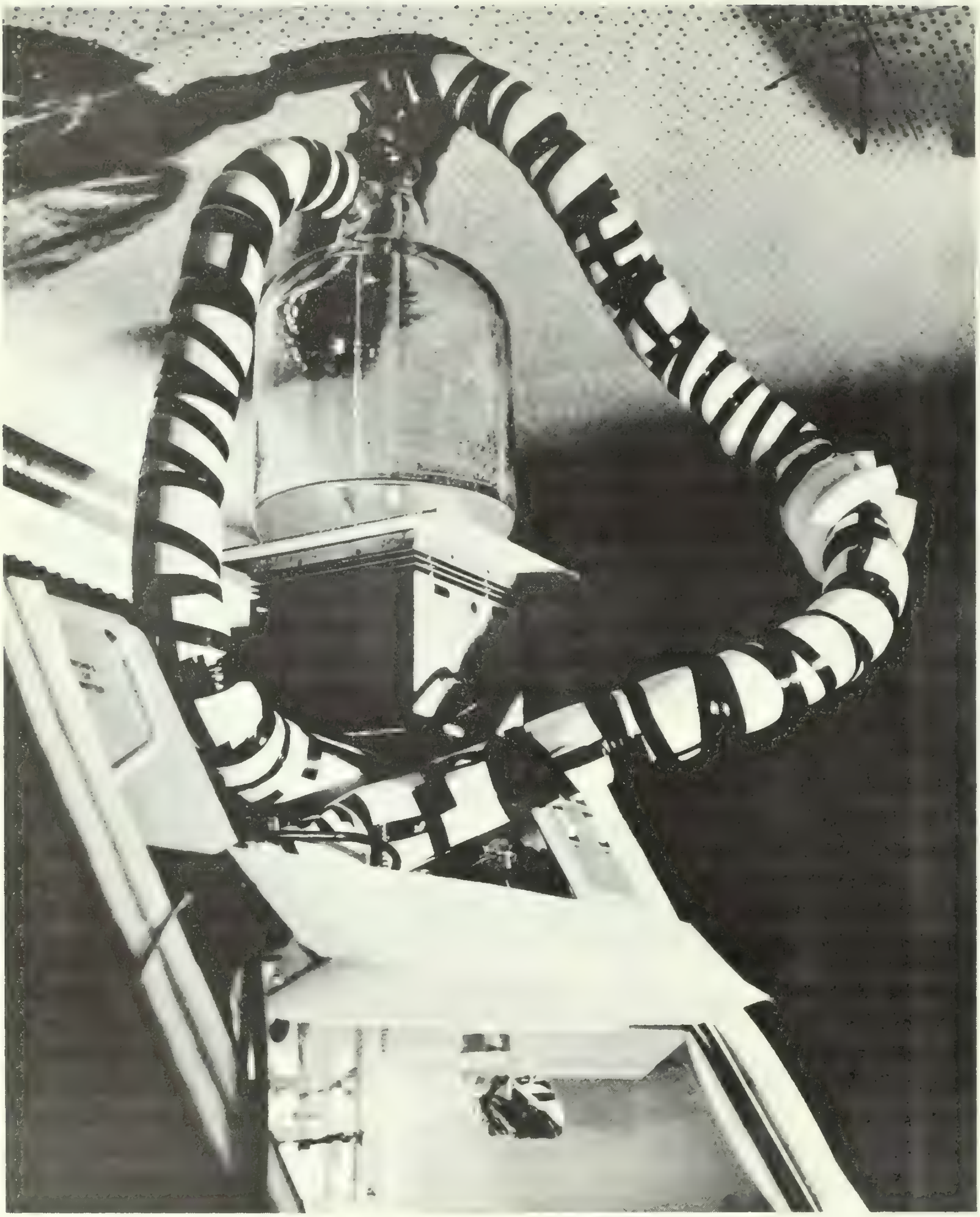

Figure 2.--Constant relative humidity was maintained in the glove box by recirculating air through the reagent bottle containing a saturated salt solution.

The EMC of each fuel was estimated at each level of relative humidity by determining the moisture content of two subsamples which were removed from the chamber after they had reached a constant weight. This usually required about 2 to 3 days. The subsamples were weighed on a balance inside the chamber. The sample moisture content was determined by drying the material in a vacuum oven for 18 hours at 212° F.

RESULTS AND DISCUSSION

The EMC curves in figure 3 illustrate how the moisture content of fine forest fuels is influenced by relative humidity. These curves should be a useful guide for comparing the response of different fuels to relative humidity, and for estimating fuel moisture levels at specific relative humidities. However, certain limitations in the data should be kept in mind. First, the EMC's at any given relative humidity vary slightly with changes in air temperature.[7] Within the range of air temperatures that occur around forested areas, the EMC of forest fuels decreases as air temperature increases. This is due to the natural tendency for adsorbed molecules to vaporize from a surface more readily as temperature increases, even though the relative humidity remains constant. However, under natural conditions, the relative humidity of the atmosphere does not usually remain constant as changes in temperature occur. Increases in temperature are usually accompanied by a corresponding decrease in relative humidity.

Second, the samples used to obtain these curves were freshly fallen leaves collected in the fall of the year. Weathering of these materials from prolonged exposure to the elements may alter their EMC's slightly. Third, constantly changing weather does not often permit fuel moisture to reach equilibrium with the surrounding atmosphere. Furthermore, the "time lag" characteristics of fine fuels vary considerably. For example, Simard[8] found that the time lag constant described by the National Fire Danger Rating System[9] varies considerably with the degree of weathering of the needles of white spruce, white pine, jack pine, and red pine. We have also observed variation in time lag characteristics of slash pine needles, depending on whether they were collected in the fall or in the spring. Freshly fallen, dead needles take on and lose water vapor much slower than needles that have weathered in the open for several months.

With these limitations in mind, the data still provide useful information about the response of these fuel materials to changes in relative humidity. To compare the EMC's of one fuel with another, we chose a range of moisture contents, 8 to 15 percent, which is accepted by fire use specialists as suitable for many applications of prescribed fire in southeastern pine forests.[10] The shadowed areas in figure 3 delineate the range of relative humidities which would produce EMC's between 8 and 15 percent, regardless of whether the EMC is approached from a dry or wet condition. By comparing the shadowed area for each fuel, one can rank each kind of fuel according to the range of relative humidities which produces EMC's between 8 and 15 percent. At any specific relative humidity, hardwood leaves tend to have relatively high EMC's, pine needles are somewhat lower, and the grasses and loblolly pine wood have the lowest EMC's.

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[7] Stamm, loc. cit.

[8] Simard, Albert J. The moisture content of forest fuels - II; Comparison of moisture content variations above the fibre saturation point between a number of fuel types. Forest Fire Res. Inst.,Dep. Forest & Rural Develop., Ottawa, Ontario. Inform. Rep. FF-X-15, 68 pp. 1968.

[9] USDA Forest Service. National Fire-Danger Rating System handbook. Category 2 Handbook, FSH2 5123.3. Washington, D. C. 1964.

[10] Cooper, R. W. USDA Forest Serv. Southeast. Forest Exp. Sta. Personal communication. 1969.

Figure 3.--Equilibrium moisture content (EMC) of fine fuel materials found in forests of the southeastern United States. (□ = EMC's obtained during desorption cycle, ○ = EMC's obtained during adsorption cycle, △ = EMC's obtained on a second adsorption-desorption cycle following the one used to obtain all other points.)

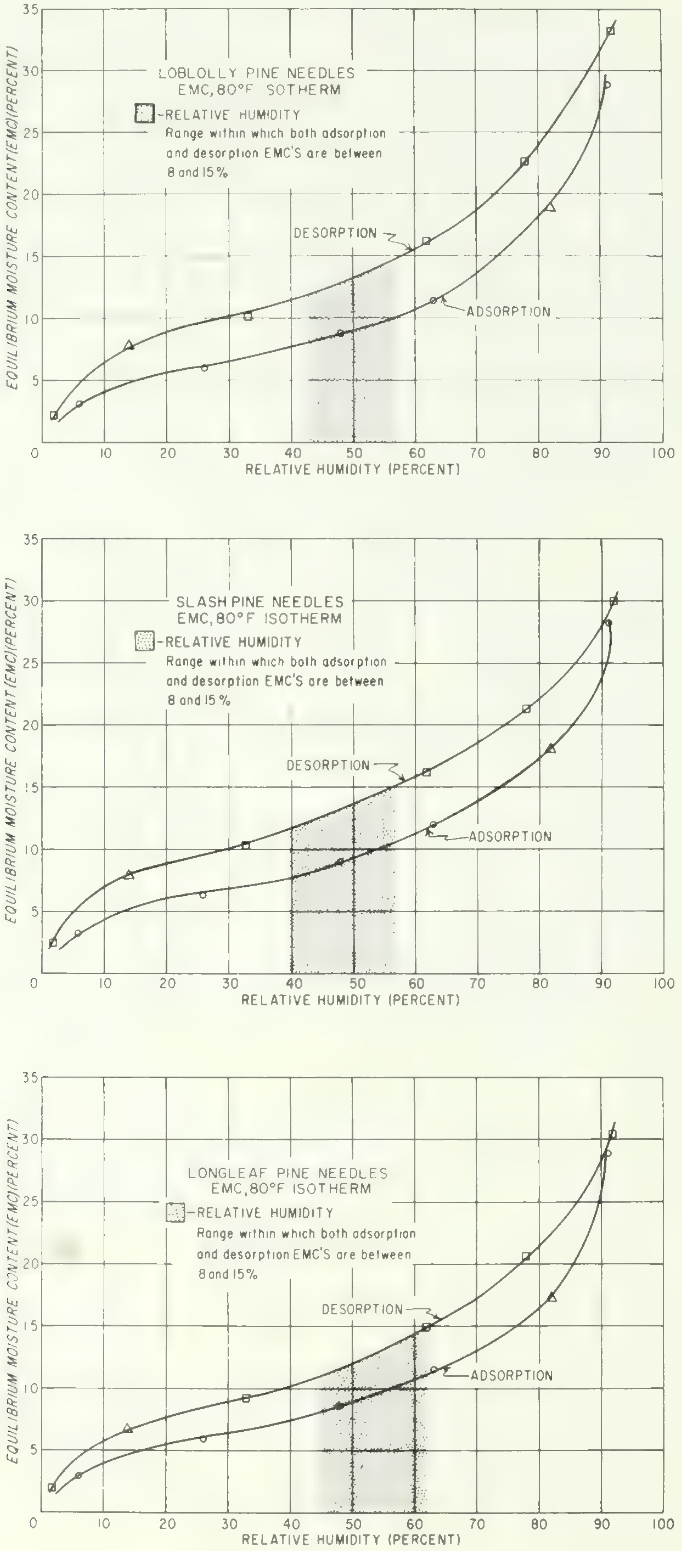


Figure 3.--(Continued)

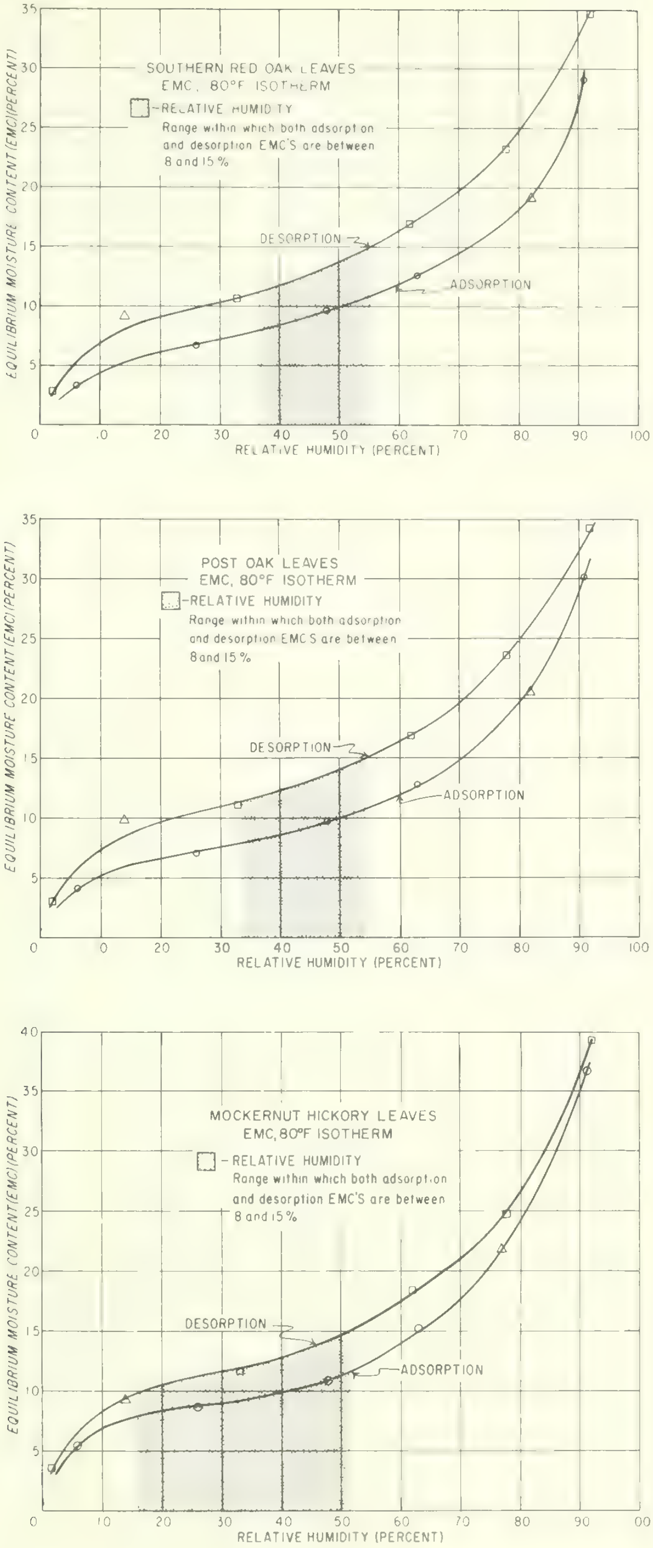
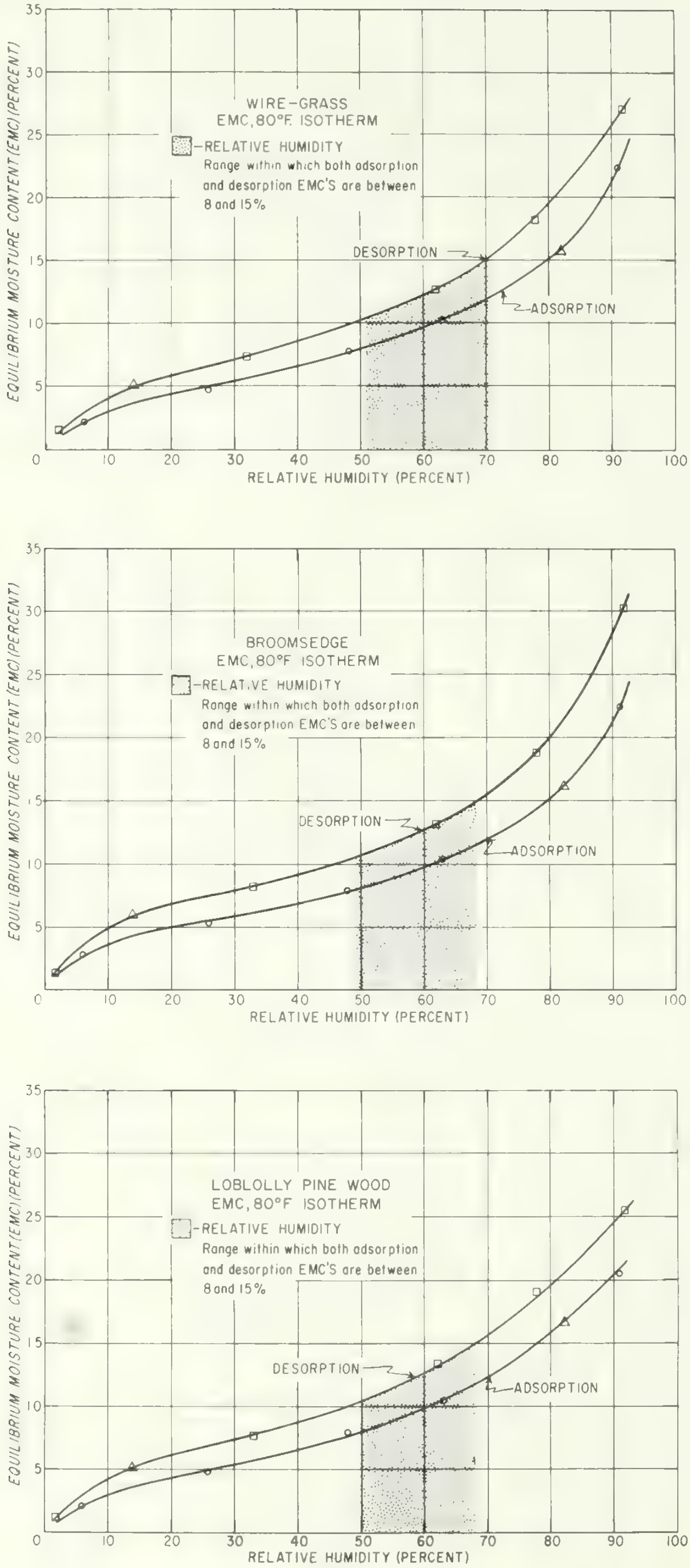


Figure 3.--(Continued)



Blackmarr, W. H.
1971. Equilibrium Moisture Content of Common Fine Fuels Found in Southeastern Forests. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-74, 8 pp.

Nine different kinds of forest litter found in ground fuel complexes of southeastern forests were subjected to stepwise changes in relative humidity to determine their equilibrium moisture content (EMC) at different levels of relative humidity.

The adsorption and desorption EMC curves for these fuels exhibited the typical hysteresis loop. At any given relative humidity, hardwood leaves usually had the highest EMC's, pine needles were somewhat lower, and grasses and loblolly pine wood had the lowest EMC's.

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Fertilization
of Young Longleaf Pine in a Cultivated Plantation

Ralph H. Hughes • James E. Jackson • Richard H. Hart

USDA Forest Service Research Paper SE -75 • January 1971

FERTILIZATION OF YOUNG LONGLEAF PINE IN A CULTIVATED PLANTATION[1]

by

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Because normal longleaf pine *(Pinus palustris* Mill.) seedlings remain in the grass stage for 6 to 7 years and require 9 or 10 years to attain sapling size (Wahlenberg 1946), they are more susceptible than other southern pines to injury by cattle. A previous study revealed that fertilization of slash pine *(P. elliottii* Engelm. var. *elliottii)* seedlings in a cultivated plantation resulted in rapid early growth (Hughes and Jackson 1962). The present study, which was conducted in an adjoining plantation, was similarly aimed at getting longleaf pine seedlings off to a vigorous start, thereby shortening the period of their susceptibility to cattle damage.

METHODS

A 3-acre area of longleaf-slash pine forest range near Alapaha, Georgia, was selected for the study. The area was clearcut, stumped, and thoroughly worked with a tandem disk-harrow. Grade 1, 1-0 longleaf pine seedlings with roots pruned to 6 inches were planted at 10- by 10-foot spacing over the entire area. Three seedlings were planted per spot during January 1958; these were thinned to one per spot at the start of the second growing season.

Soils were Klej loamy sand and Plummer sand. Soil analysis of the surface 6 inches showed 15 pounds P, 35 pounds K, and 840 pounds Ca per acre. The pH was 5.4. A mixture of $0.05N$ HCl and $0.025N$ H_2SO_4 was used as the extractant for P, K, and Ca. The P was determined colorimetrically by the modified Truog method. The K was determined by means of a flame photometer, and CaO was read turbidometrically by comparison with standards after the Ca had been precipitated with $Na_2C_2O_4$.

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The study area was divided into plots of 16 trees, and treatments and measurements were confined to the center square of four trees in each plot. The outer row of trees on each side of these subplots was left as an isolation strip.

The study design was a randomized complete block with three replications of 40 fertilizer treatments. The treatments are outlined in table 1. Single applications of fertilizer were made in February or March; when split applications were made, half the material was applied in February or March and half in June. Subsurface applications were placed 4 to 6 inches below the soil surface. Fertilizer was applied from 1958 through 1965.

The first 27 treatments made up a 3x3x3 factorial. Treatments 31 through 38, with the 100-22-42 and 200-44-83 treatments from the 3x3x3, made up a second factorial for comparing the effect of split fertilizer applications at several rates. Two treatments from the 3x3x3, with treatments 39 and 40, made up a third factorial for comparing the effect of placement at two rates.

In all treatments, N was supplied by ammonium nitrate (NH_4NO_3), P by superphosphate (20-percent P_2O_5, 8.8-percent P), K by muriate of potash (60-percent K_2O, 49.8-percent K), and Mg by magnesium sulfate ($MgSO_4$). The minor element mixture contained 12.7-percent $MnSO_4$, 4.3-percent $ZnSO_4$, 4.8-percent $CuSO_4$, 0.5-percent $Na_2B_4O_7$, and 4.3-percent $FeSO_4$. Lime was supplied by dolomitic limestone ($CaCO_3 \cdot MgCO_3$).

The entire area was cultivated with a tandem disk-harrow as often as needed to control weeds. Weeds close to the pine seedlings were removed by hand.

Heights of trees were measured at the close of each growing season. Annual measurements of diameters at breast height were begun in 1964. Bud development was rated at the beginning of the second growing season in order to provide an early indication of subsequent growth response to fertilization.

RESULTS

The program of annual cultivation and fertilization was successful in getting the longleaf pine seedlings off to a rapid start. At age 2 years from planting, 79 percent of the surviving seedlings had emerged from the grass stage and had grown to a height of at least 4 inches (fig. 1). At age 5, 89 percent were sapling-sized trees measuring more than 4½ feet.

Bud development.—Bud development was accelerated by fertilization with P. Applications of P at the 44-lb. rate in the factorial experiment produced seedlings with the most mature buds at the beginning of the second growing season (fig. 2). Neither N nor K affected bud development significantly, although fertilization with N produced somewhat lower ratings than did fertilization with K.

Table 1.—Fertilizer treatments applied

No.	Pounds per acre in a 2-foot radius around tree						Application
	N	P	K	Mg	Lime	Minor elements	
1-27	0, 100, or 200	0, 22, or 44	0, 42, or 83	0	0	0	Surface, single
28	200	44	83	0	2,000	25	Surface, single
29	200	44	83	42	0	25	Surface, single
30	400	87	166	42	0	25	Surface, single
31	50	11	21	0	0	0	Surface, single
32	400	87	166	0	0	0	Surface, single
33	600	131	249	0	0	0	Surface, single
34	50	11	21	0	0	0	Surface, split
35	100	22	42	0	0	0	Surface, split
36	200	44	83	0	0	0	Surface, split
37	400	87	166	0	0	0	Surface, split
38	600	131	249	0	0	0	Surface, split
39	100	22	42	0	0	0	Subsurface, single
40	200	44	83	0	0	0	Subsurface, single

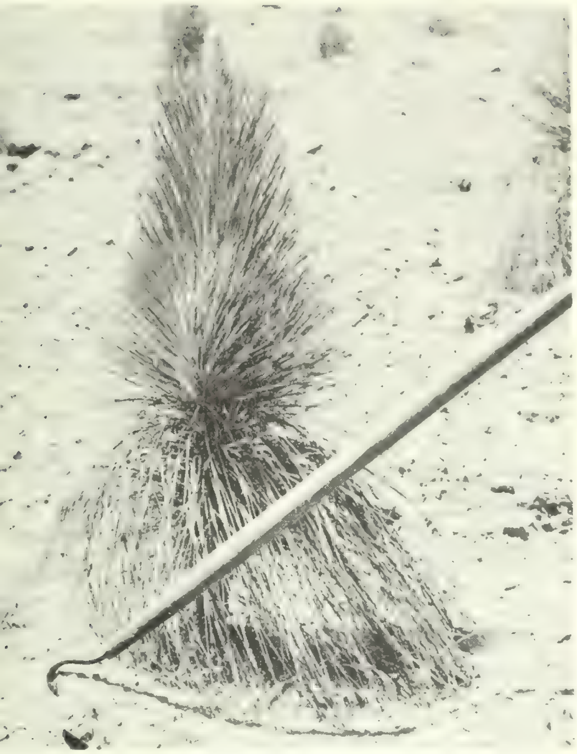

Figure 1.—A 30-inch-tall longleaf pine seedling at age 2 years from planting. Annual cultivation and fertilization resulted in its early emergence from the grass stage.

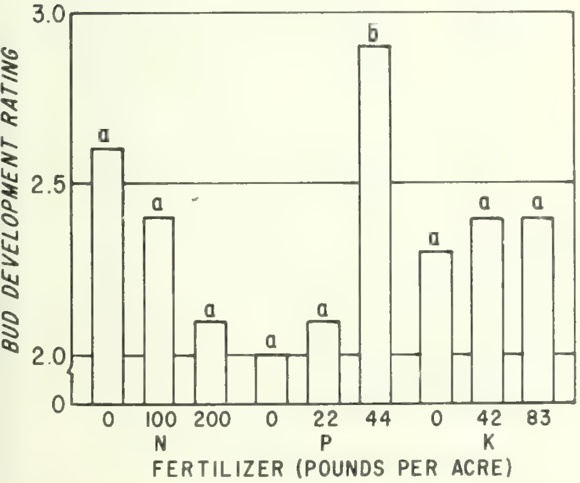

Figure 2.—Average bud development at beginning of second growing season in relation to fertilizer component: a rating of 2 indicates opening bud with first green showing and 3 indicates active bud with extending needles. Within a fertilizer component, ratings labeled by the same letter are not significantly different at the 5-percent level by Duncan's multiple-range test.

Survival.—Phosphorus application significantly increased survival. By the eighth year, 63 percent of the trees receiving 44 lb. of P per acre per year and only 39 percent of those receiving no P were left. Nitrogen had the opposite effect. By the eighth year, 67 percent of the trees receiving no N and only 36 percent of those receiving 200 lb. of N were left. A similar pattern was noted in the fourth year. In both years, survival was as high with 22 lb. of P per acre as with 44 lb. and as high with 100 lb. of N per acre as with no N. Potassium appeared to have no significant effect on survival. None of the NPK interactions were significant.

Growth.—Phosphorus significantly improved early growth, but N and K had no significant effect. At age 4, trees fertilized with P were 2.1 feet taller than those receiving no P. There was no difference between trees receiving 22 or 44 lb. of P per acre. At age 8, the trees fertilized with P at either rate were still 2 feet taller than trees receiving no P.

Between ages 4 and 8, annual applications of fertilizer did not have a significant effect on growth. At age 8, the average height of the unfertilized checks was 19.1 feet and that of all fertilized trees in the factorial experiment was 20.3 feet. Trees fertilized with combinations containing P at the 22- and 44-lb. rates emerged more quickly from the grass stage than did those fertilized with combinations without P, and this superiority was maintained at age 8. From 1962 through 1965, the average height growth for both the unfertilized checks and all fertilized trees in the factorial experiment was about 4 feet per year.

Height growth was apparently affected by interactions of N and K with P in the factorial experiment. At age 4, a significant reduction in height accompanied applications of N without P (fig. 3) and applications of K without P (fig. 4). The responses to K in combinations with N and P and to N in combinations with K and P were not significant. At age 8, there was a clear response to P with no significant interactions with N or K.

Diameter (d.b.h.) measurements of sapling-sized trees begun at age 4 also revealed the response to P. Those trees fertilized with combinations containing P at the 22- and 44-lb. rates were almost an inch larger in diameter at age 8 than were the trees fertilized with combinations without P (table 2).

The favorable response of longleaf pine to P fertilization in this study was very similar to the results obtained previously for slash pine in an adjoining plantation (Hughes and Jackson 1962). Design and layout of the two factorial studies were the same. The slash pine plantation was established in 1957 and was fertilized in 1957 and 1958; the longleaf plantation was established in 1958 and fertilized annually. Average height of trees at age 5 in relation to P fertilization was:

Rate of P *(lb./acre)*	**Slash pine** *(feet)*	**Longleaf pine** *(feet)*
0	15.8	6.7
22	17.5	9.1
44	17.6	9.3

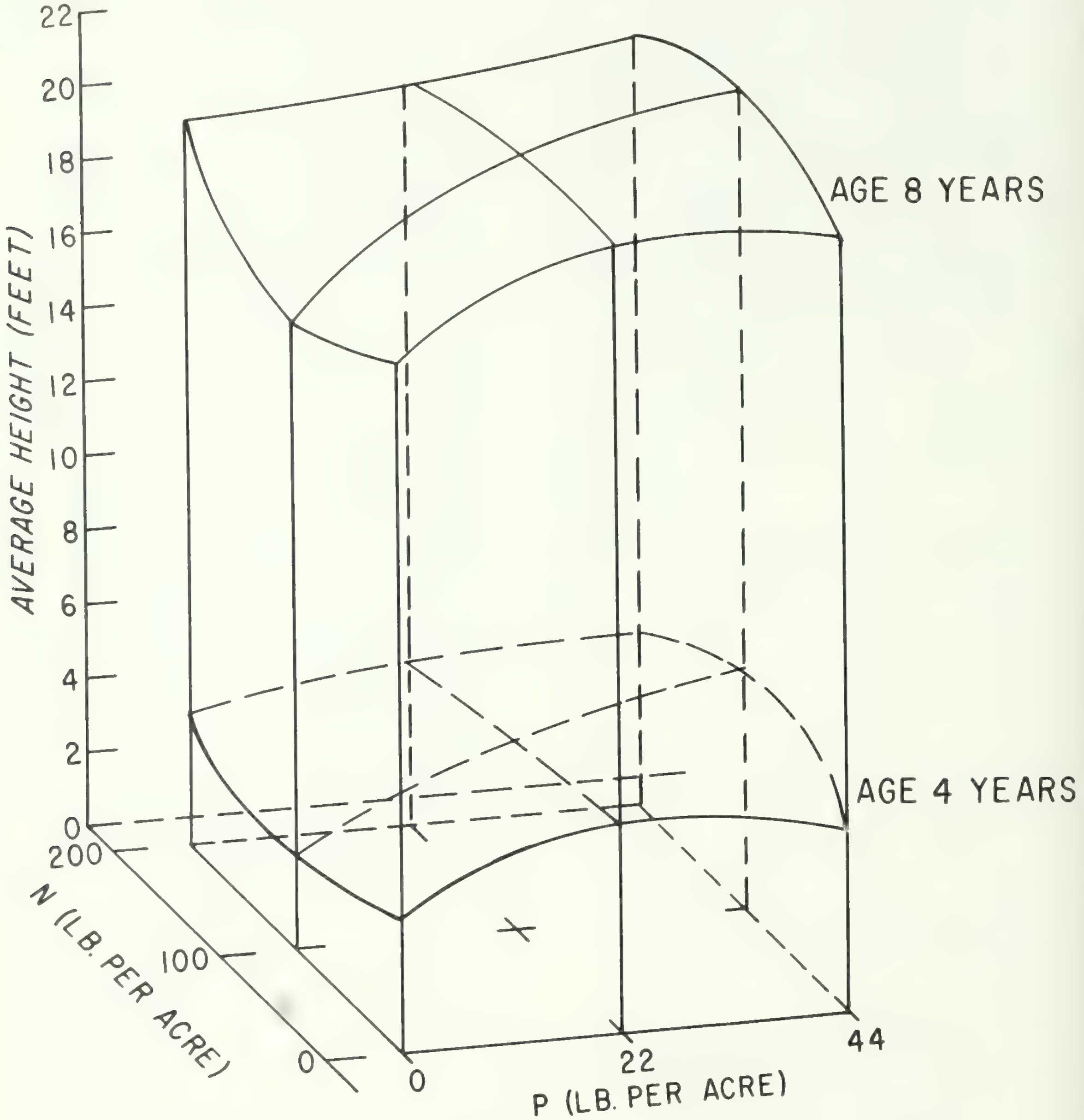

Figure 3.—Height of longleaf pine at ages 4 and 8 years from planting in response to N and P fertilization.

Minor elements.—No significant influence as detected from application of lime, Mg, r the mixture of minor elements including In, Zn, Cu, B, and Fe.

Split and subsurface application.—The rees that received split applications of fer- lizer in February or March and again in June averaged about the same size as those that received a single application in February or March. Likewise, subsurface application 4 to 6 inches deep gave no better results than did broadcast application. Hence, from the standpoint of tree growth, the single surface application was cheapest and most practical.

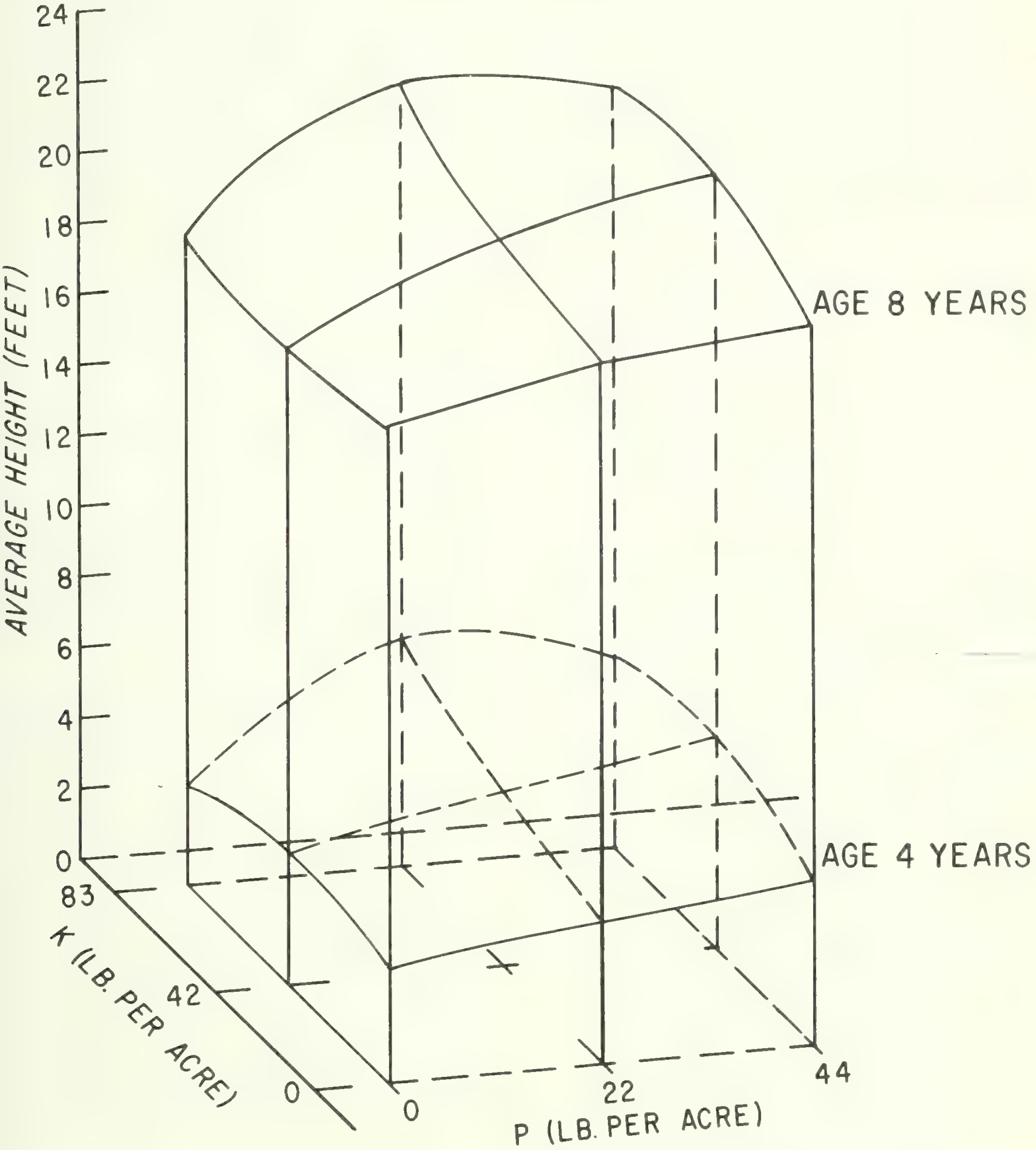

Figure 4.—Height of longleaf pine at ages 4 and 8 years from planting in response to K and P fertilization.

Table 2.—Average diameter (d.b.h.) of longleaf pines at end of eighth year in relation to fertilizer component

Component	Rate[1]		
	0	1	2
		D.b.h. (inches)[2]	
N	4.0	4.1	4.1
P	3.4	4.2	4.3
K	3.9	4.1	4.2

[1] A 3x3x3 factorial with N at 0, 100, and 200 pounds per acre, P at 0, 22, and 44 pounds per acre, and K at 0, 42, and 83 pounds per acre. Rates specified apply only to the circular area with a 2-foot radius around each tree.

[2] Means connected by the same line are not significantly different at the 5-percent level.

Cultivation.—Prompt cultivation in both directions between rows of trees and some hand hoeing around trees were required to control weeds. Without cultivation, fertilizer placement might well have had a more pronounced effect upon tree growth. Crabgrass (*Digitaria sanguinalis* (L.) Scop.), panicum grasses (*Panicum* spp.), dogfennel (*Eupatorium compositifolium* Walt.), and blackberry (*Rubus cuneifolius* Pursh) were the most persistent invaders.

Weeding was needed most frequently during the second through the fourth years from planting. An ocular estimate in June 1959 showed that surface application of fertilizers containing N and P increased the percentage of weed cover on the circular areas around each tree, as follows:

Rate of N *(lb./acre)*	Weeds *(percent)*	Rate of P *(lb./acre)*	Weeds *(percent)*
0	10	0	10
100	19	22	20
200	24	44	22

In contrast, the immediate influx of weeds after subsurface application of fertilizer was negligible.

Insect and disease damage.—Brown spot needle blight, caused by the fungus *Scirrhia acicola* (Dearn.) Siggers, was noted on 14 percent of the seedlings 1 year after planting and on 46 percent after 2 years. During the second year, the trees that received no P or no K had a significantly greater amount of infected needle surface than did those fertilized with P at the 22-lb. rate or with K at the 42-lb. rate. The incidence of brown spot on trees fertilized with P at the 44-lb. rate or with K at the 83-lb. rate did not differ significantly from that on the unfertilized control trees or those fertilized with P or K at the lower rates. By age 3, the percentage of needle surface infected had dropped sharply; by age 5, when most trees had emerged from the grass stage, this percentage was negligible.

Fusiform rust (*Cronartium fusiforme* (Hedgc. & Hunt)) was the only other disease noted. Although it was a major pest in nearby slash pine plantations, its incidence and effect in the longleaf pine plantation were negligible.

Tipmoths (*Rhyacionia* spp.) and pitch moths (*Dioryctria amatella* Hulst) attacked some sapling-sized trees, usually in the terminal bud. The infestations were light and did not differ by treatment.

DISCUSSION

The results indicate that the subplots consisting of four trees planted at 10- by 10-foot spacing were adequate for measuring differences in treatment effects until the seedlings had initiated height growth. Thereafter, these subplots and the circular area of fertilization around trees probably were too small to measure treatment effects reliably. Roots possibly could have extended to neighboring subplots as early as age 4. At 5 years from planting, Kaufman (1968) found that 81 of 256 roots of slash pine were over 20 feet long and that three were over 30 feet.

Survival, although not a problem in the adjoining slash pine plantation, was poorest in the longleaf pine plantation when N was applied at the highest rate or when the application lacked P. Allen and Maki (1955) found that longleaf pine seedlings that received complete fertilizer survived drought during the first year better than did unfertilized seedlings but that the seedlings did not respond to N alone. In contrast to agricultural crops, pine trees grow best at relatively low levels of soil N (Kramer and Kozlowski 1960).

During the period of height development, rapid growth of most trees was maintained and few trees died, suggesting that the detrimental effect of N during the grass stage did not continue during the later period. Those trees which survived the heavy application of N grew off reasonably well without obvious stunting or symptoms of N toxicity.

In extrapolating the results to a management situation, the absence of competing herbaceous vegetation leaves much to conjecture. In neighboring plantations, however, intensive site preparation followed the same year by planting of improved forage species and slash pine seedlings did not stimulate rapid seedling growth (Hughes 1965). On the other hand, summer fallowing with a tandem disk-harrow the first year and establishment of forage species the second year did stimulate such growth.

Results of this study suggest that fertilizing for reasonable productivity of improved forage species should adequately satisfy tree requirements. While the 9:2:4 ratio of NPK (2:1:1 ratio of N-P_2O_5-K_2O) tested here is acceptable and commonly recommended for satisfactory production of improved forage species, lesser portions of N, perhaps P alone, would seem more desirable for establishing longleaf pine. Nitrogenous fertilizers could be applied and forage species established after the trees had emerged from the grass stage.

SUMMARY

Forty fertilizer treatments were replicated three times in a cultivated plantation of longleaf pine on a flatwoods site near Alapaha, Georgia. Seedlings were planted in 1958, clean tilled, and fertilized within a circle (2-foot radius) annually through 1965. Meaningful results were limited because of the small size of the fertilized subplots, i.e., the four trees centered within a 16-tree plot spaced 10 by 10 feet.

Early bud development of planted seedlings was a reliable indicator of response to treatment. Seedlings showing best bud development at the start of the second growing season were first to emerge from the grass stage and were subsequently the largest trees.

Three main findings emerged from the NPK factorial experiment: (1) for survival, a positive response to P and a negative response to N; (2) for early growth of seedlings, a positive response to P; and (3) for subsequent growth of sapling-sized trees, no significant response to fertilization.

In the NPK factorial, trees fertilized with P at the rate of 44 pounds per acre measured 3.0 feet taller at age 8 than did trees that received no P and 2.2 feet taller than did trees that received no fertilizer. Survival varied from 63 percent for trees fertilized with P at the 44-lb. rate to only 39 percent for trees fertilized with combinations without P.

Tests involving (1) minor elements with lime or magnesium added to heavy applications of NPK fertilizers, (2) split applications of fertilizers at five widely varying rates, and (3) subsurface application of fertilizers did not reveal significant increases in growth when compared with single surface applications of NPK fertilizers. Subsurface applications had the advantage of preventing the rapid influx of weeds which followed surface applications of mixed fertilizers containing N and P.

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